USING SUBSTANCES TO ENHANCE PERFORMANCE: A PSYCHOLOGY OF NEUROENHANCEMENT

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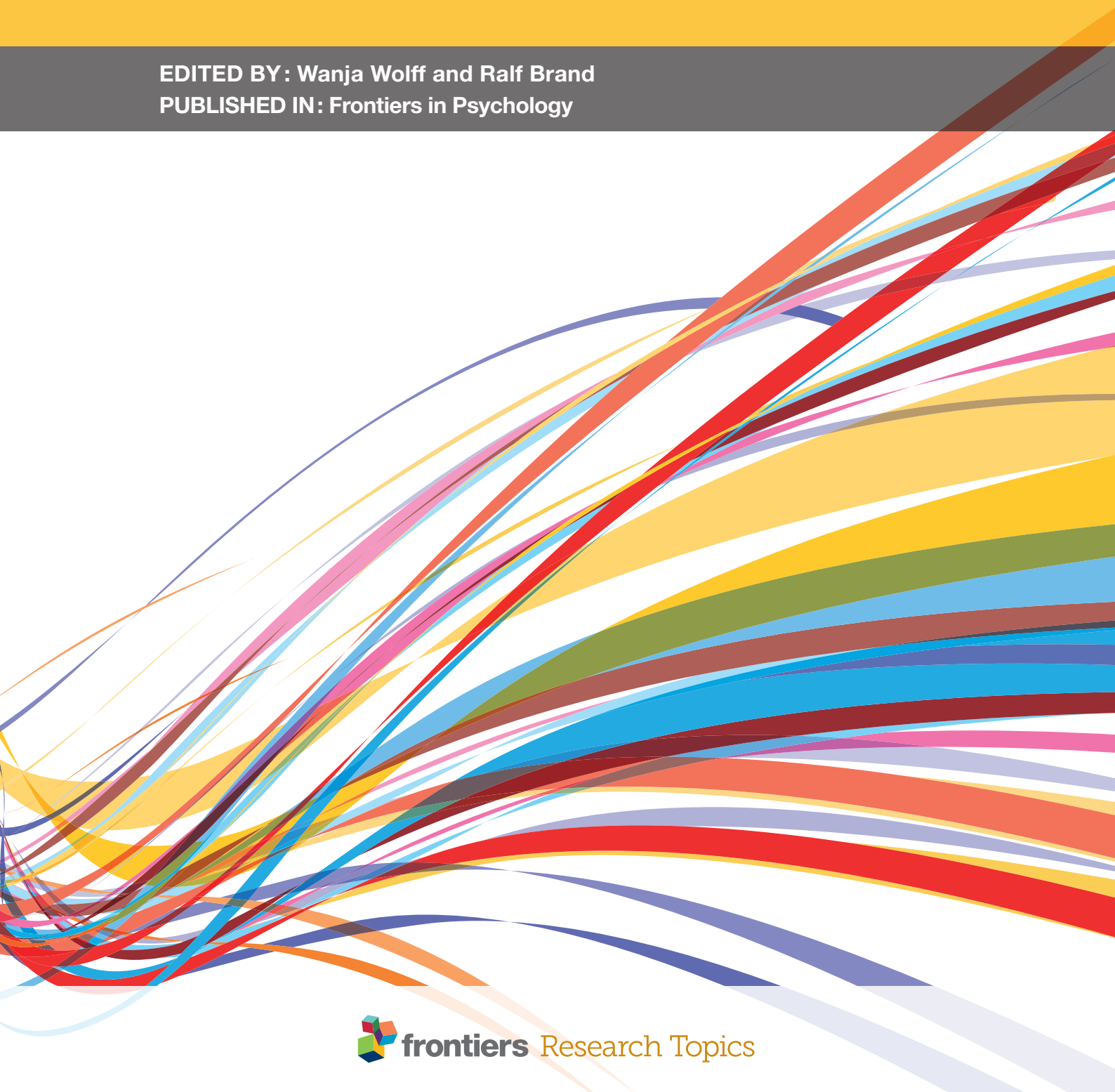

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USING SUBSTANCES TO ENHANCE PERFORMANCE: A PSYCHOLOGY OF NEUROENHANCEMENT

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Neuroenhancement (NE) is a behavior conceptualized as the use of a potentially psychoactive substance to enhance ones' already proficient cognitive capacities. Depending on the specific definitions used, prevalence estimates vary greatly between very low 0.3% (for illicit substances) to astonishingly high 89% (for freely available lifestyle substances). These variations indicate that further research and more conceptual and theoretical clarification of the NE construct is dearly needed.

The contributions of this research topic aim to do just that. Specific questions addressed are: How prevalent is NE behavior? How can NE research profit from the already more evolved field of social science research on doping in sports? How is NE perceived by the public? What psychological processes and variables play a role in the decision to neuroenhance? A wide array of methodological approaches is used to investigate these questions. The topics contributions range from theoretical to experimental accounts on NE, and they utilize a diverse set of methods ranging from qualitative to neuroscientific approaches.

The research presented here represents a first step towards what we have labeled a psychological approach to NE. By addressing the questions above, this research topic hopefully advances our understanding of NE behavior. As with every new field of research, new answers always prompt new questions. In light of what we know now about NE, we hope that the findings presented here will be pursued by other researchers in the future. Clearly, the endeavor to understand NE behavior has only just begun.

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EDITORIAL
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Editorial: Using Substances to Enhance Performance: A Psychology of Neuroenhancement

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Keywords: neuroenhancement, cognitive enhancement, doping, behavior, performance enhancement

The Editorial on the Research Topic

Using Substances to Enhance Performance: A Psychology of Neuroenhancement

Within the scientific community and among the general public there exists a lively debate regarding the use of drugs for the enhancement of cognitive performance. The defining feature of this type of functional substance (ab)use behavior is the *assumed functionality* a user ascribes to a chosen substance for the intended goal (e.g., Wolff and Brand, 2013; Wolff et al., 2014). According to this behavioral approach, such Neuroenhancement (NE) behavior is best understood as a goal-directed behavior that should be investigated with research that is informed by psychological theorizing. Since there is currently a lack of such research, this research topic sets out to address this gap.

An important step to advance our understanding of NE is to integrate the normative ethical debate on NE with the actual empirical evidence (Forlini and Hall). In the topics first contribution, Forlini and Hall argue that the ethical debate on the *ought* of NE (what should be done) is pursued almost entirely in isolation of what actually *is* the case. Forlini and Hall conclude that the current ethical discussion is based upon false assumptions. Namely the assumptions that NE substances have large positive effects on performance and that NE is highly prevalent. Added to these false assumptions is a lack of understanding of the psychological factors that play a role in the NE decision (Forlini and Hall).

In their comparative review of the effectiveness of pharmacological and non-pharmacological products for NE purposes, Caviola and Faber underline the first point of Forlini and Hall's analysis: Pharmacological means of performance enhancement (e.g., Methylphenidate, Modafinil) do not reliably outperform non-pharmacological ones (e.g., sleep) in terms of effectiveness. However, pharmacological means are perceived as unacceptable compared with non-pharmacological methods of performance enhancement. Faber et al.'s quantitative study indicates that the single strongest predictor of how unacceptable one evaluates NE to be is the perceived unfairness of such behavior. Thus, although no differences in effectiveness exist, pharmacological methods of NE are evaluated less positively.

The second point of Forlini and Hall's analyses referred to the implied high overall prevalence of NE. However, so far, NE prevalence has mostly been investigated in student populations. In an attempt to broaden this scope, two contributions have investigated NE prevalence outside the academic context (Dietz et al.; Sattler and Schunck). Focused on readers of a German economic newspaper, Dietz et al. found that the lifetime prevalence for lifestyle drugs NE (i.e., freely available over the counter products like Red Bull®) and illicit or prescription drugs NE was 88 and 19%, respectively. Although their sample was non-representative, these results show that NE is not merely a phenomenon among university students. Analyzing data from a representative sample of German employees, Sattler and Schunck found a considerably lower lifetime prevalence of 2.96% for prescription drugs NE. This finding aligns well with Forlini and Hall's claim that the ethical debate overstates the actual prevalence of NE.

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As we have written elsewhere (Wolff et al., 2014) and in accordance with the analysis of Forlini and Hall, the NE debate lacks theory-driven research on the psychological drivers of NE. The remaining contributions have addressed this issue from different angles.

In their research perspective, Englert and Wolff carve out the relationship between NE and self-control: NE can be understood as an act of self-control that might lead to positive (performance enhancement) or negative (health issues) consequences. The postulate that NE represents a form of self-regulation is consistent with the behavioral approach to NE and is supported by the contributions of Jensen et al. and Vargo and Petróczi. In their qualitative study, Jensen et al. compared the stress and coping patterns of NE users and non-users. They found that users applied avoidant coping strategies until stress levels were unbearable. As a last resort, users then switched to the "problem focused" approach of using drugs to fulfill university requirements (Jensen et al.). Similarly, in their qualitative study, Vargo and Petróczi found that NE is used to "satisfy adaptive needs related to their work and academic demands (p. 10)." These contributions (Englert and Wolff; Jensen et al.; Vargo and Petróczi) again showcase the importance of a behavioral approach to NE that focuses on the means-end relationship represented by NE behavior. However, the contributions by Jensen et al. and Vargo and Petróczi also report that NE use seems to be more associated with a feeling of needing to catch up. This is opposed to the implicit notion of most NE definitions which suggest that NE is aimed at achieving superior performance.

In their research perspective, Zelli et al. outline a social cognitive approach that builds upon the already much more developed—and conceptually similar—field of research on doping in sports. Indeed, concepts and methodologies from this domain might well be transferable to the NE domain. For example, so called indirect measures of implicit attitudes have successfully been used in social science research on doping (Brand et al., 2014). Since NE, like doping, appears to be a socially sensitive topic and since implicit measures are less prone to faking, these measures are particularly promising for NE research as well. Part of the validation process of such measures is to understand the cortical processes that contributed to an implicit attitude score. In their contribution, Schindler and Wolff use Electroencephalography (EEG) to investigate the degree of *implicitness* that is likely to be reflected in an indirect measure of implicit attitudes toward performance enhancing substances.

The contributions of Sattler and Schunck, Brand et al., and Brand and Koch apply well-established psychological theories to NE. Sattler and Schunck's study uses the Five Factor Model of Personality and shows that NE users display lower values on conscientiousness, and higher values on neuroticism, compared with non-users. Brand et al. apply Drug Instrumentalization Theory in an attempt to broaden the view on the behavioral basis of functional substance (ab)use behaviors: Individuals can use a variety of substances (e.g., prescription drugs, illicit drugs) as instruments to achieve a variety of different goals (e.g., overcoming fatigue, facilitating social interactions). Their empirical study indicates that university students consistently use one type of drug (e.g., prescription drugs) as a means to achieve a variety of goals (as opposed to a more specialized approach of using specific drugs for specific goals). Finally, Brand and Koch use the Prototype-Willingness model to predict the willingness and intentions to use NE. In addition, they show that the theoretical links between attitudes and NE intentions was weakened when participants were given false (high) prevalence information. This finding brings us back to the point made by Forlini and Hall: A normative ethical debate that is disconnected from empirical evidence and which implies an overly high NE prevalence is problematic. Brand and Koch's results indicate that such a public discussion (building upon false premises) can, in turn, have repercussions on individuals' intentions regarding NE use.

The contributions in this research topic offer various distinctive angles on the phenomenon of NE: Engaging in ethical considerations with a focus on psychological processes will hopefully lead to better alignment between normative ethical debates and empirical evidence. Research perspectives have the potential to catalyze further theory-driven research. Qualitative approaches and research using neuroscientific methodology represent two distant points on the continuum of possible ways to understand the NE phenomenon. These different approaches can, respectively, offer either a wide, holistic perspective or a narrow, specific perspective on a phenomenon. Finally, using empirical tests based on psychological theories to differentiate users from non-users or to predict future use will hopefully prove to be a further step toward a better understanding of the psychological drivers of NE. We believe these different perspectives can mutually benefit each other and inform further, much needed research on NE behavior.

AUTHOR CONTRIBUTIONS

WW and RB both contributed substantially to this manuscript.

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PERSPECTIVE
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The *is* and *ought* of the Ethics of Neuroenhancement: Mind the Gap

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Ethical perspectives on the use of stimulants to enhance human cognitive performance (neuroenhancement) are polarized between conservative and liberal theories offering opposing advice on whether individuals have a right to use neuroenhancers and what the social outcomes of neuroenhancement might be. Meanwhile, empirical evidence shows modest prevalence and guarded public attitudes toward the neuroenhancement use of stimulants. In this *Perspective*, we argue that the dissonance between the prescriptions of ethical theories (what ought to be) and empirical evidence (what is) has impaired our understanding of neuroenhancement practices. This dissonance is a result of three common errors in research on the ethics of neuroenhancement: (1) expecting that public perspectives will conform to a prescriptive ethical framework; (2) ignoring the socio-economic infrastructures that influence individuals' decisions on whether or not to use neuroenhancement; and (3) overlooking conflicts between fundamental ethical values namely, safety of neuroenhancement and autonomy. We argue that in order to understand neuroenhancement practices it is essential to recognize which values affect individual decisions to use or refuse to use neuroenhancement. Future research on the ethics of neuroenhancement should assess the morally significant values for stakeholders. This will fill the gap between what ought to be done and what is done with an improved understanding of what *can* be done within a particular context. Clarifying conflicts between competing moral values is critical in conducting research on the efficacy of substances putatively used for neuroenhancement and also on neuroenhancement practices within academic, professional and social environments.

Keywords: neuroenhancement, neuroethics, normative ethics, empirical ethics, values, stakeholders, behavior

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BACKGROUND

Ethical perspectives on the use of substances to enhance human cognitive performance (neuroenhancement) have become polarized between conservative and liberal normative theories (Racine, 2010; Forlini and Racine, 2013). These theories stem from respective political stances on technology and human enhancement that fundamentally disagree about whether individuals have a right to use neuroenhancers and about the potential social outcomes of neuroenhancement (Hughes, 2009; Reiner, 2013).

The *liberal* or *meliorist* approach maintains that "[h]uman history — or at least human progress — is in great part the story of enhancement" (Buchanan, 2010) as reflected in the development of tools, technology, and organized societies. Evolution, for its part, might be

considered as the "original" process that enhanced human capacities and characteristics. From this standpoint enhancement should continue to be pursued because it promises to reduce suffering and improve the quality of human life (Caplan, 2003; Savulescu, 2006; Harris, 2007; Bostrom and Sandberg, 2009; Buchanan, 2010). At the extreme of this liberal perspective is *transhumanism*, a movement that embraces science and technology in the hope of becoming "post-human, beings with vastly greater capacities than present human beings have" (Bostrom, 2003).

The *conservative* or *anti-meliorist* standpoint strives to preserve "human nature". From this position, enhancement poses a risk to human existence because it may produce undesirable physical and social changes in human beings (Fukuyama, 2002; President's Council on Bioethics, 2003; Sandel, 2004). Evolution, conservatives argue, should not to be meddled with. The risk is that in "enjoying the benefits of biotechnology, we will need to hold fast to an account of the human being, seen not in material or mechanistic or medical terms but in psychic and moral and spiritual ones" (President's Council on Bioethics, 2003). Biotechnology erodes the building blocks of the "human dignity" as exemplified by the discipline and effort that are required to attain excellence and that promote human flourishing and our identity (Kass, 2003).

There are many more nuanced positions between these conservative and liberal views (Hughes, 2009; Reiner, 2013). However, these opposing points of view represent extremes in the broader "culture wars" that underlie bioethics debates in the USA about stem cell research and end-of-life care (Callahan, 2005; Hughes, 2009; Racine, 2010). The "culture wars" reflect "radical moral-political divisions in the public domain" (Racine, 2010) that mirror disagreements between conservative and liberal moral and political positions. The fundamental differences between conservative and liberal approaches to enhancement make it difficult to come to a shared understanding of how to proceed at the institutional and community levels. Some authors have declared an ethical stalemate because they believe that the conservative and liberal positions can never be reconciled and so cannot produce ethical advice for stakeholders (e.g., students, health professionals, policy makers, academic institutions, members of the general public) (Roache and Clarke, 2009; Banja, 2011).

Despite their differences, these two poles in the neuroenhancement ethics debate both unwittingly and uncritically promote the "myth of cognitive enhancement" (Zohny, 2015). That is, they both assume that putatively neuroenhancing substances do in fact enhance and that their use is widespread and increasing. Neither of these assumptions is well supported by empirical evidence (Lucke et al., 2011).

First, most of the prescription medications labeled as neuroenhancers (i.e., prescription stimulants such as Ritalin, Adderall and Modafinil) have little, if any, enhancing effect in healthy individuals (Repantis et al., 2010a,b). A recent systematic review reported that modafinil provides some benefit in complex tasks but criticized the studies for their lack of sensitivity, reproducibility and ecological validity (Battleday and Brem, 2015).

Second, the empirical survey evidence finds a very modest prevalence of neuroenhancement use of stimulants, even in academic environments, an alleged hotspot of use (Smith and Farah, 2011). Public attitudes toward their use are guarded, but not entirely conservative, reflecting a politically moderate stance that is sensitive to salient ethical issues (Fitz et al., 2014). Public attitudes also vary according context and experience with neuroenhancement (Schelle et al., 2014). These survey data do not support the claims of widespread and increasing neuroenhancement use often made by proponents of the two dominant normative approaches.

Why do stakeholder views and actions differ from what is widely assumed by the two ethical perspectives? How should we marry normative theories (what ought to be) with empirical evidence (what is) in this bioethics debate? As several authors have argued, it is important to bring the two together because it is "not only sufficient for an ethicist to discuss the moral rightness or wrongness of a certain practice on a theoretical level, but also to think about the conditions under which a norm can be effective in society" (Birnbacher, 1999) (de Vries and Gordijn, 2009; Salloch et al., 2012). In this *Perspective*, we argue that the dissonance between the opposing normative theories and empirical data on stakeholder attitudes has impaired our understanding of neuroenhancement practices. We describe key features of this dissonance and outline an approach to research on the ethics of neuroenhancement that may help to bridge the gap between normative and empirical perspectives.

THREE COMMON ERRORS IN RESEARCH ON THE ETHICS OF NEUROENHANCEMENT

Empirical reality often limits human agency in ways that conflict with normative or theoretical views (Potter, 1971; Hurst, 2010). In the context of neuroenhancement, there are at least three instances in which real life situations have contributed to errors in ethical reflection.

Expecting that Public Perspectives will Conform to a Prescriptive Ethical Framework

Studies that elicit the perspectives of stakeholders on neuroenhancement often identify the same issues discussed in academic discourse on the topic (Schelle et al., 2014). However, there are two important differences between stakeholder perspectives and formal normative reflections. First, stakeholder studies report the coexistence within individuals of conflicting ethical perspectives (i.e., ambivalence) on neuroenhancement and its acceptability in medical and academic environments (Banjo et al., 2010; Hotze et al., 2011; Forlini and Racine, 2012b). This ambivalence is often evident in students' reactions to analogies between neuroenhancement use of caffeine and sports doping, which can be taken as representing liberal and conservative perspectives, respectively. Two studies have shown that students analogise neuroenhancement and sports doping

in competition but differentiate the two on the basis of the magnitude of steroid effects compared to the effects of caffeine or prescription stimulants (Forlini and Racine, 2012b; Bell et al., 2013). In another study, 56% of a sample of German university students saw no *moral* difference between neuroenhancement and the use of caffeinated substances. However, 44% also said that prescription stimulants and caffeine differed in their side effects, medical risks and legal consequences (e.g., in using a medical prescribed substance illegally). Just under half (46%) of these students either *did not* or *could not* differentiate the two types of substances. These students were uncertain about the most appropriate policy framework (permissive or restrictive).

Second, the ethical acceptability of neuroenhancement seems to be a matter of degree for many stakeholders. They often express reservations about its acceptability or specify conditions under which it would be ethically acceptable. For example, neuroenhancement could be acceptable to some if its use was controlled and moderate (Forlini and Racine, 2009; Bell et al., 2013). The use of neuroenhancing substances was found to be more acceptable when used to: *enhance to the norm* (Cabrera et al., 2015), *enable* the true self (Riis et al., 2008), *normalize* the performance of underperforming colleagues (Sabini and Monterosso, 2005) or *restore* cognitive function caused by normal age-associated memory impairment (Banjo et al., 2010) than when used to *enhance above the norm*. The more acceptable conditions of use were thought to reflect degree of medical necessity, a key factor for many in distinguishing between enhancement and treatment (Cabrera et al., 2015) as well as a concern for fairness and equality of opportunity (Sabini and Monterosso, 2005). Acceptability also varied with whether the target for enhancement was seen as connected with the authenticity of the individual (Riis et al., 2008; Berg et al., 2009). Stakeholders seemed less willing to accept the neuroenhancement of mood, emotions, and memory because they were seen to be more closely associated with self-identity than aspects such as concentration or alertness. These empirical findings on the degrees of acceptability of neuroenhancement may not fit neatly into the principled approach of normative ethics. They also challenge the myth of widespread stakeholder interest in neuroenhancement (Farah et al., 2004; Greely et al., 2008) because stakeholder perspectives are not as resoundingly liberal as often assumed by proponents of enhancement.

Ignoring the Socio-Economic Infrastructures That Influence Decisions

Empirical ethics research not only studies the normative values held by stakeholders; it also describes their actions and behaviors in situations that call for a moral choice. Empirical inquiry has revealed that some stakeholders feel under pressure to perform and believe that they have "no choice" except to use neuroenhancers, despite also believing that this choice should be an individual or personal matter (Forlini and Racine, 2009). Stakeholders are also more willing to use neuroenhancers if they believe that their peers are doing so in order to avoid being at a social disadvantage (Franke et al., 2012a; Sattler et al., 2013). Other studies have found more modest (Fitz et al., 2014) and sometimes opposite effects of peer pressure (Forlini et al., 2015). These differences may reflect cultural or contextual differences in stakeholder perspectives that merit further investigation.

Equality of access was another major ethical concern for stakeholders. The majority agreed that if neuroenhancement was allowed then it should be available to everyone but very few thought that the cost of neuroenhancers should be covered by health insurance (Bergstrom and Lynoe, 2008; Hotze et al., 2011; Forlini and Racine, 2012a). The roles of peer pressure and equality of access show that professed ethical values do not always translate into behavior and that socioeconomic factors may influence decisions to use or not to use neuroenhancement as much as ethical values.

Bioethicists often assume "an implausible degree of rationality", individual freedom and consistency in human decisions, motivations, and actions (Solomon, 2005). An individual's decision to use neuroenhancement is multi-faceted and ethical norms may only comprise one factor. There may also be inconsistencies between personal values and behavior because when "faced with an ethical dilemma, people do not always think about what they ought to do in isolation from what they are currently doing" (Ives and Draper, 2009). Fear of being at a disadvantage, or worries about scarce health resources, may influence attitudes toward enhancement more than values like personal choice or equality of opportunity. Schelle et al. (2014) postulate that stakeholders, especially neuroenhancement users, can experience cognitive dissonance, which is "the discomfort experienced when one's actions don't reflect one's beliefs." This dissonance will persist until values catch up with the demands of the socioeconomic context in which they are meant to govern behavior.

Overlooking Incompatibilities Between Fundamental Values

Empirical data shows that stakeholders have difficulty balancing safety and autonomy. On the one hand, many stakeholders believe that using neuroenhancement is a personal choice for which individuals must take responsibility (Forlini and Racine, 2009; Franke et al., 2012a; Bell et al., 2013). Part of this responsibility is to make decisions that may affect one's health (Forlini and Racine, 2009; Banjo et al., 2010) and to evaluate the risks of doing so. Neuroenhancers are prepared to tolerate mild to moderate adverse side effects but are deterred by the prospects of long-term and serious side effects (Franke et al., 2012b; Sattler et al., 2013). These beliefs reflect the liberal perspective on neuroenhancement which champions the autonomy of individuals and their right to incur whatever risks that they are comfortable with incurring (Sententia, 2004). On the other hand, for many stakeholders safety is paramount. Even when presented with a hypothetically safe cognitive enhancer in a study vignette, Banjo et al. (2010) found that, "physicians mistrust safety claims regarding pharmaceuticals." For these physicians, safety concerns "were not offset by the benefit afforded the individual" (Banjo et al., 2010). Similarly, Hotze et al. (2011) reported that a hypothetically safe neuroenhancer was seen as unacceptable because they were regarded as being "too risky" (for reasons unspecified in the survey) or likely to

cause negative behaviors (e.g., making a soldier more aggressive). These perspectives are consistent with the conservative stance that the uncertain safety of neuroenhancement trumps individual autonomy (Heinz et al., 2012).

Stakeholders' perspectives on the values of safety and autonomy are well defined but the challenge is to balance the two in ways that place socially agreed limits on acceptable forms of neuroenhancement. The use of an enhancer that was unsafe and used under coercion would be unacceptable, regardless of political stance. Given this, it is may be useful to explore stakeholder trade-offs between these two values under scenarios that vary by *degrees in* safety and autonomy. This would illuminate the level of risk that was seen as appropriate for an individual to take in pursuit of neuroenhancement and views on the extent to which individuals should be prevented from taking this risk to protect them from harm.

BRIDGING *IS* AND *OUGHT* WITH "CAN"

Empirical data can help bioethicists to understand the values of stakeholders so that theory and policies can be made more relevant and effective (Ives and Draper, 2009). If principles "are too abstract or practically not feasible" then normative ethics fails to guide action (de Vries and Gordijn, 2009). Until normative-empirical tensions are unwound it would be difficult to carry out a constructive discourse that informs policy. As more empirical data on stakeholder perspectives about the ethics of neuroenhancement emerge, normative bioethicists may have to revisit their discussions of ethical principles for two reasons. First, this process may create a negotiated space between what people "ought" to do and what they actually "can" do within existing socio-economic frameworks. Discovering what can be done will require normative and empirical research to test the degrees of public acceptability. This may identify an "ethical tipping point" in a debate still plagued with ambivalence about many of the salient issues. Second, empirical data may uncover unethical behavior that does not respect traditional social values. If, for example, we discovered that certain professional environments obliged employees to take cognitive enhancers in order to be more productive most would object on the grounds that this practice was coercive, regardless of whether or not the enhancer was safe.

Normative ethics might also have the task of reinforcing values and promoting ethical behavior. Drawing attention to and working through tensions between normative principles and behavior may help to refine the most significant ethical values for stakeholders. This exercise is sorely needed to, first, distance research on the ethics of neuroenhancement from the culture wars and an uncritical acceptance of the myths of cognitive enhancement, and second, to increase social dialogue and deliberation on the acceptability of neuroenhancement and thereby reinvigorate the mandate of bioethics to enrich societal perspectives by closely examining contentious issues.

CONCLUSION

Future research on the ethics of neuroenhancement should assess the values that are most morally significant to the public in order to better understand how the public approaches neuroenhancement. We need to fill the gap between what ought to be done and what is done by a better understanding of what *can* be done in a particular social context. In doing so, we should avoid assuming that principles and practices, concepts, and experience will not change. As Solomon (2005) comments, practice "guidelines persist, taking a life if their own, while the conditions that motivated them change." It is the responsibility of bioethicists to "formulate and reformulate our ethical theories" (Frith, 2012) to keep the reflections relevant to public policy debates.

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CF drafted, revised, and finalized the manuscript. WH refined content and revised the manuscript.

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Pills or Push-Ups? Effectiveness and Public Perception of Pharmacological and Non-Pharmacological Cognitive Enhancement

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We review work on the effectiveness of different forms of cognitive enhancement, both pharmacological and non-pharmacological. We consider caffeine, methylphenidate, and modafinil for pharmacological cognitive enhancement (PCE) and computer training, physical exercise, and sleep for non-pharmacological cognitive enhancement (NPCE). We find that all of the techniques described can produce significant beneficial effects on cognitive performance. However, effect sizes are moderate, and consistently dependent on individual and situational factors as well as the cognitive domain in question. Although meta-analyses allowing a quantitative comparison of effectiveness across techniques are lacking to date, we can conclude that PCE is not more effective than NPCE. We discuss the physiological reasons for this limited effectiveness. We then propose that even though their actual effectiveness seems similar, in the general public PCE is perceived as fundamentally different from NPCE, in terms of effectiveness, but also in terms of acceptability. We illustrate the potential consequences such a misperception of PCE can have.

Keywords: cognitive enhancement, neuroenhancement, methylphenidate, modafinil, caffeine, physical exercise, computer training, sleep

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INTRODUCTION

Cognitive enhancement is defined as "interventions in humans that aim to improve mental functioning beyond what is necessary to sustain or restore good health" (Dresler et al., 2013, p. 529). There are several means for such cognitive enhancement, both pharmacological (PCE) and non-pharmacological (NPCE). We summarize literature on the effectiveness[1] of six often discussed and prevalent potential enhancements, namely caffeine, methylphenidate, and modafinil for PCE, and computer training, physical exercise, and sleep for NPCE. We conclude that PCE is not more effective than NPCE and discuss the physiological reasons for this limited effectiveness. We then illustrate that although they have similar effect sizes, PCE is perceived by the general public as fundamentally different from NPCE, in terms of effectiveness and but also acceptability.

[1]Note that all effect sizes refer to Cohen's d (or its adjusted versions like Hedge's g), whereby small effect sizes are defined by a value around 0.2, moderate effect sizes by around 0.5, and large effect sizes by around 0.8 (Cohen, 1992). Where available, we report the exact effect sizes.

EFFECTIVENESS OF PHARMACOLOGICAL COGNITIVE ENHANCEMENT

Methylphenidate

Methylphenidate is a pharmacological psychostimulant of the phenethylamine and piperidine classes and best known under its marketing label Ritalin®. It acts as a reuptake inhibitor, increasing dopamine and norepinephrine levels (Sulzer et al., 2005). Although methylphenidate is usually prescribed for attention deficit hyperactivity disorder, evidence suggests that it can enhance cognitive performance in healthy individuals.

In meta-analyses, it was found that methylphenidate exhibits large positive effects ($d = 1.4$; Repantis et al., 2010) on memory performance, that delayed episodic memory is improved by a moderate ($d = 0.45$; Ilieva et al., 2015), and short-term episodic memory by a smaller effect size ($d = 0.20$; Ilieva et al., 2015). This suggests that methylphenidate primarily enhances memory consolidation but neither encoding nor retrieval (cf. McGaugh and Roozendaal, 2009). A review concluded that verbal learning appears to be improved by methylphenidate, whereas visual learning remains unaffected (Linssen et al., 2014). Methylphenidate further improves working memory. Small, but robust, positive effects on spatial working memory have been reported in many studies (for reviews, see Repantis et al., 2010; Franke et al., 2014; Linssen et al., 2014; Ilieva et al., 2015). Further, methylphenidate has been shown to improve inhibitory control and speed of processing (Ilieva et al., 2015). The effects of methylphenidate on attention are less consistent. Most studies have reported no significant improvements in attention (cf. Repantis et al., 2010), or even negative effects (e.g., Rogers et al., 1999). However, a few studies have found small improvements in attention and vigilance (cf. Linssen et al., 2014). It has been speculated that methylphenidate might also affect motivational and emotional functions. However, although some data seem to support this hypothesis (Volkow et al., 2014), to date there is too little evidence to draw definite conclusions.

The enhancing effects of methylphenidate are greater in low-performing than high-performing individuals (Finke et al., 2010). Methylphenidate can even impair the performance of high-performers (Mattay et al., 2000; de Wit et al., 2002; Farah et al., 2009). One study, for example, has shown that methylphenidate can disrupt attentional control in certain individuals (Rogers et al., 1999). Further, methylphenidate consistently increases heart rate, and increased blood pressure, headache, anxiety, nervousness, dizziness, drowsiness, and insomnia have been reported occasionally (Repantis et al., 2010).

Modafinil

Modafinil is a wakefulness-promoting agent originally developed to treat narcolepsy, but it is also applied as PCE (Sahakian and Morein-Zamir, 2007). The neuropsychology of modafinil is not yet well understood. It is assumed that dopamine and norepinephrine are involved in its mechanisms (Ballon and Feifel, 2006; Volkow et al., 2009).

Modafinil consistently improves attention in non-sleep deprived as well as sleep-deprived healthy individuals (for reviews, see Repantis et al., 2010; Franke et al., 2014; Battleday and Brem, 2015). In particular, experiments have shown improvements in sustained attention (Baranski et al., 2004; Randall et al., 2005; Dean et al., 2011) and selective attention (Schmaal et al., 2013). The effects of modafinil on memory are less clear. Some studies report beneficial effects of modafinil on spatial and numeric working memory (Müller et al., 2004). However, a review of 31 randomized controlled studies reported no significant changes in memory (Repantis et al., 2010).

It is assumed that the effects of modafinil strongly depend on the individual baseline performance (Randall et al., 2005). Similar to methylphenidate, modafinil appears to positively affect low-performing individuals to a greater extent than high-performing individuals (Finke et al., 2010). Further, the effects of modafinil are strongest for cognitively demanding tasks (Müller et al., 2013). However, it potentially impairs creative and flexible thinking (Müller et al., 2013; Mohamed, 2014) and can increase feelings of overconfidence in judgment (Baranski et al., 2004). Further, Repantis et al. (2010) reported that potential, but rare, side effects of modafinil are headache, dizziness, gastrointestinal complains, nervousness, restlessness, and insomnia.

Caffeine

Caffeine is an adenosine receptor antagonist, applicable inter alia in the forms of coffee, tea, or energy drinks. It is assumed that caffeine stimulates neural activity through higher noradrenaline emission (Smith et al., 2003; Ferré, 2008).

Several studies have shown that caffeine improves sustained attention and alertness in simple tasks (for a review, see Einöther and Giesbrecht, 2013). The beneficial effects in complex tasks, however, are less consistent (Rogers and Dernoncourt, 1998; Heatherley et al., 2005). Further, caffeine can improve both encoding and response speed to new stimuli (Riedel et al., 1995; Warburton et al., 2001), as well as long-term memory consolidation (Borota et al., 2014). However, it is not clear whether reported memory improvements could be due to an increase in attention during encoding (Nehlig, 2010).

Effects of caffeine are moderated by level of habitual intake (Attwood et al., 2007), age (Nehlig, 2010), and even personality (Smith, 2002). Caffeine can have negative effects at high doses (from ∼400 mg). Such high doses can reduce motivation (Lieberman, 1992), and potentially also cognitive performance. Hasenfratz and Bättig (1994), for example, reported that doses of 420 mg doses of caffeine resulted in more commission errors and slower processing rate in cognitive tasks than lower doses. Further, withdrawal of heavy caffeine consumption can result in adverse side effects including headaches, increased subjective stress, fatigue, and decreased alertness (e.g., Dews et al., 2002; Juliano and Griffiths, 2004).

In sum, evidence regarding methylphenidate, modafinil, and caffeine shows that PCE can significantly improve certain cognitive functions healthy individuals. Most effects, however, are only moderate in size. Further, they are moderated by different factors, prominently baseline performance, and PCE dose, and improvements in one domain seem to go along with impairments in another. In other words, none of the three reviewed PCEs appears to be able to radically enhance cognition. Why not?

EXPLANATIONS FOR THE LIMITED EFFECTIVENESS OF PCE

The pharmacological dynamics of PCE are not yet well understood. Many PCEs influence the levels of neuromodulators such as dopamine or serotonin, whose effects are complex and intertwined. PCE has been described to show an inverted U-shaped relationship between cognitive performance and dosage (Husain and Mehta, 2011; cf. **Figure 1**): evidence suggests that methylphenidate, modafinil, and caffeine are capable of enhancing certain cognitive functions up until a certain point, at which increased consumption will lead to cognitive decline. This is because both too high and too low concentrations of a certain neurotransmitter can impair cognitive function (**Figure 1A**; e.g., Hannestad et al., 2010). Accordingly, low baseline performers gain more benefits from PCEs than high baseline performers do, who might already exhibit optimal neurotransmitter concentration (Finke et al., 2010).

Further, improvements in one cognitive function often seem to be accompanied by impairments in another (**Figure 1B**). This is because an increase in substance level might improve one cognitive function (F1) but at the same time impair another (F2) due to differential drug sensitivity (Husain and Mehta, 2011).

EFFECTIVENESS OF NON-PHARMACOLOGICAL COGNITIVE ENHANCEMENT

Computer training

Specifically designed computerized training programs can enhance cognitive functions (for a review, see Dresler et al., 2013). In particular, improvements in memory, attention (Smith et al., 2009), visual processing speed (Parsons et al., 2014), and executive functions (Basak et al., 2008; Nouchi et al., 2012) have been demonstrated, with effects lasting over a period of up to 3 months (Mahncke et al., 2006). A notable body of research has focused on the enhancement of working memory through computerized tasks with increasing difficulty over time. Such tasks can also improve executive functions and fluid intelligence (Jaeggi et al., 2008; Bergman Nutley et al., 2011), although the transferability to performance in every-day life has been questioned (Dahlin et al., 2008; Redick et al., 2013).

Commercial computer games can also improve cognition (Dresler et al., 2013). The evidence is particularly strong for the improvement of visual skills, including spatio-visual resolution (Green and Bavelier, 2007), mental rotation (Okagaki and Frensch, 1994), contrast sensitivity (Li et al., 2009), visual search (Castel et al., 2005), tracking of object color and identity (Sungur and Boduroglu, 2012), spatio-visual attention (Green and Bavelier, 2003), and the number of objects that can be attended (Achtman et al., 2008). Further, regular gamers appear to have improved cognitive flexibility (Colzato et al., 2010), multi-tasking ability (Strobach et al., 2012), enumeration skills (Green and Bavelier, 2006), and psychomotor skills (Kennedy et al., 2011).

The effect sizes of computerized training and games range from medium to large, depending on the trained and tested cognitive domain (Mahncke et al., 2006; Smith et al., 2009; Schmiedek et al., 2010). It is not clear, however, whether these effects can be explained by the similarity of the perceptual and attention tasks to the training programs (Oei and Patterson, 2014), and the extent to which they transfer to untrained tasks in real environments (Okagaki and Frensch, 1994; Fuyuno, 2007; Owen et al., 2010). There is no evidence of substantial negative side effects of computer training.

Physical Exercise

Acute exercise, in the form of brief bouts of exercise or high intensity training such as anaerobic running, can improve cognitive functions (for reviews, see Tomporowski, 2003; Lambourne and Tomporowski, 2010; Dresler et al., 2013; for methodological criticism, see Dietz, 2013). The cognitive

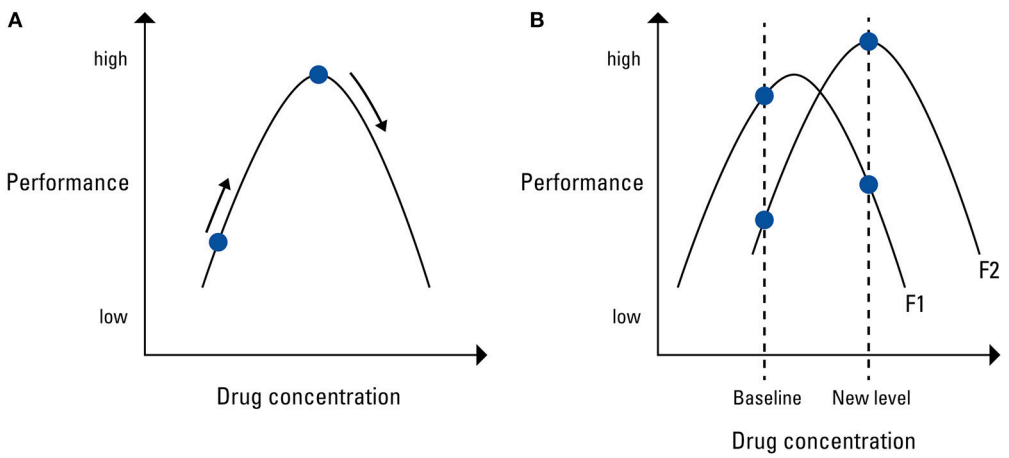

FIGURE 1 | (A) Schematic display of the inverted-U shaped function between positive effect on cognitive performance and drug concentration in the brain. **(B)** An increase in substance level might improve one cognitive function but impair another. Adapted from Husain and Mehta (2011).

enhancing effects of acute physical exercise have been linked to an increase in motivation and general arousal level (Brisswalter et al., 2002). Acute exercise may cause a similar physiological response as physical stress does, which has been linked to better episodic memory consolidation (Weinberg et al., 2014). Acute exercise improves memory performance by a medium effect size, but the effects vary depending on the specific type of exercise (Lambourne and Tomporowski, 2010). In particular, speed of learning (Winter et al., 2007), episodic memory (Weinberg et al., 2014), and general long-term memory (Coles and Tomporowski, 2008) can be improved. Some of these effects can persist over a period of up to 48 h after exercising (Weinberg et al., 2014).

Regular exercise has been shown to increase brain volume in gray and white matter regions (Colcombe et al., 2006). In particular, the size, cerebral blood flow, and connectivity of the anterior hippocampus, an area responsible for spatial memory, are increased through exercise (Burdette et al., 2010). Regular exercise can improve memory, attention, executive functions, and processing speed in general (Hillman et al., 2008; Smith et al., 2010). It also seems to improve academic performance, intelligence, perceptual, mathematical, and verbal skills in school-aged children (Sibley and Etnier, 2003).

Excessive acute exercise can lead to fatigue, dehydration, and decreased blood glucose levels, which can impair cognitive functions such as long-term memory (Cian et al., 2000, 2001; Grego et al., 2004). There is no evidence of negative side effects for regular exercise.

Sleep

Sleep exhibits positive effects on cognition, particularly on memory (for a review, see Dresler et al., 2013). The underlying mechanisms are not yet understood. In particular, it is not clear whether the improved memory is due to active consolidation during sleep or to passive homeostatic mechanisms (Tononi and Cirelli, 2003). Studies suggest that neuronal patterns are reactivated during sleep, indicating a replay of memories (Wilson and McNaughton, 1994; Ji and Wilson, 2007; Diekelmann, 2014), and potentially promoting the formation of new neuronal connections (Yang et al., 2014).

Sleep can improve memory beyond the normal condition in rested/non-sleep deprived individuals (e.g., Jenkins and Dallenbach, 1924; Fischer et al., 2002; Diekelmann and Born, 2010), also memories acquired after sleep (Diekelmann, 2014). While the positive effects of sleep on declarative memory are moderate (Gais et al., 2006), the effects on procedural and perpetual memory can be very large (Karni et al., 1994; Fischer et al., 2002). Sleep can also increase creativity (Dresler, 2012) by triggering creative insights (Ritter et al., 2012) and speeding up problem solving (Wagner et al., 2004). Increased creativity has been particularly linked to REM sleep (Cartwright, 1972; Glaubman et al., 1978), the sleep stage in which most intense dreaming occurs.

Even naps (of 6 min or more) during the daytime can improve some memory systems to a similar degree as a whole night of sleep in non-sleep-deprived individuals (Mednick et al., 2003; Lahl et al., 2008).

Individual factors such as gender, hormonal level, and mental health moderate the effects of sleep (Genzel et al., 2009; Dresler et al., 2010). Further, there is evidence that too much sleep can impair cognition in the long run. A number of correlational studies have shown that sleep for more than 9 h per 24 h is associated with impaired cognitive function in elderly individuals (e.g., Benito-León et al., 2009; Devore et al., 2014). However, no causal connection has been demonstrated.

In sum, the reviewed evidence suggests that computer training, physical exercise, and sleep can moderately enhance cognitive functions. It appears, therefore, that NPCE techniques are similarly effective as current PCE techniques. Whether the effects of NPCE are limited by analogous restrictions with inverted-U shaped relationships like those for PCE is not yet clear.

PUBLIC PERCEPTION OF PHARMACOLOGICAL AND NON-PHARMACOLOGICAL COGNITIVE ENHANCEMENT

The evidence presented above suggests that both currently available PCE (methylphenidate, modafinil, caffeine) and NPCE (computer training, physical exercise, sleep) are moderately effective in improving cognition. However, their effects are dependent on individual conditions, situational conditions, and the cognitive domain under study. There are a lack of experimental studies that directly compare the effects of PCE to NPCE, and it is difficult to undertake comparative meta-analyses of those studies that do exists, as they focus on different aspects of cognition (cf. Franke et al., 2014). Hence, we cannot draw a definite conclusion whether PCE or NPCE is more effective. Our qualitative analysis, however, suggests that the PCEs available to date are not more effective than NPCEs.

This, however, stands in sharp contrast to how people perceive PCE as opposed to NPCE. The general public views PCE—with the exception of caffeinated beverages—as fundamentally different from NPCE, both in terms of effectiveness and in acceptability. Several studies confirm this.

Most lay people would not even consider NPCE to be a form of cognitive enhancement. It is hard to imagine someone being concerned about their competitor going for a run to outperform them at the job interview. This is very different from the scenario where the competitor takes a "smart pill." Lay people overestimate the effectiveness of PCE (Ilieva et al., 2013), and they express strong negative views toward its use (for a review, see Schelle et al., 2014). Unfairness is a particularly relevant concern in competitive settings (Faber et al., under review; also cf. Santoni de Sio et al., in press), at least when the explicit goal of PCE use is to improve cognition (Faber et al., 2015a). Such worries are unheard of in the case of NPCE, and they might in many cases be primarily rooted in the novelty or "unnaturalness" of PCE (Caviola et al., 2014), rather than justified threats to values like fairness posed by PCE.

Such a gap between the actual effectiveness of PCE as compared to NPCE should be seen as more than an interesting

phenomenon of lay psychology, as real life phenomena could arise from it. There is a lively debate on the ethics of cognitive enhancement (for overviews, see Bostrom and Sandberg, 2009; Maslen et al., 2014), and scientists warn about overenthusiasm about the possibilities current PCEs offer (e.g., Farah, 2015; Sahakian et al., 2015). Such an overestimation of PCE effectiveness (paired with an underestimation of potential side-effects) could on the one hand lead to calls for certain people to take such substances, for example when they work in jobs with a high responsibility for other people's lives (for discussions see e.g., Santoni de Sio et al., 2014; Maslen et al., 2015). On the other hand, it could also lead to severe stigmatization of users in competitive settings (Faulmüller et al., 2013).

Moreover, the views individuals hold of PCE can alter how PCE influences performance, namely when these individuals act in groups (Faber et al., 2015b). Whether or not PCE can improve group performance depends on intra-group psychological processes, which depend on the group members' perceptions and expectations about PCE. Imagine a group where some members take a certain PCE and others do not. If the non-using group members overestimate the efficacy of this PCE, they might rely more on the performance of the users in the group and themselves exert less effort to contribute to the group's goal. By causing such "social loafing" (Latané et al., 1979) the PCE could even reduce the performance of the group. Hence, a PCE technique that is an enhancement of individual performance for pharmacological reasons can act as an impairment for a group for psychological reasons like a misperception of efficacy (cf. Faber et al., 2015b).

CONCLUSION

We conclude that both currently available PCE and NPCE techniques can enhance human cognition to a significant, albeit moderate degree and that both are subject to moderating variables. While the actual effectiveness of both types of enhancement appears to be similar, their public perception, which in large part follows perceptions of effectiveness, is not. We hope that future research will attempt to quantitatively compare the effectiveness of PCE and NPCE, which may lead to a more balanced debate about the possibilities of cognitive enhancement.

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Why is Cognitive Enhancement Deemed Unacceptable? The Role of Fairness, Deservingness, and Hollow Achievements

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We ask why pharmacological cognitive enhancement (PCE) is generally deemed morally unacceptable by lay people. Our approach to this question has two core elements. First, we employ an interdisciplinary perspective, using philosophical rationales as base for generating psychological models. Second, by testing these models we investigate how different normative judgments on PCE are related to each other. Based on an analysis of the relevant philosophical literature, we derive two psychological models that can potentially explain the judgment that PCE is unacceptable: the "Unfairness-Undeservingness Model" and the "Hollowness-Undeservingness Model." The Unfairness-Undeservingness Model holds that people judge PCE to be unacceptable because they take it to produce unfairness and to undermine the degree to which PCE-users deserve reward. The Hollowness-Undeservingness Model assumes that people judge PCE to be unacceptable because they find achievements realized while using PCE hollow and undeserved. We empirically test both models against each other using a regression-based approach. When trying to predict judgments regarding the unacceptability of PCE using judgments regarding unfairness, hollowness, and undeservingness, we found that unfairness judgments were the only significant predictor of the perceived unacceptability of PCE, explaining about 36% of variance. As neither hollowness nor undeservingness had explanatory power above and beyond unfairness, the Unfairness-Undeservingness Model proved superior to the Hollowness-Undeservingness Model. This finding also has implications for the Unfairness-Undeservingness Model itself: either a more parsimonious single-factor "Fairness Model" should replace the Unfairness-Undeservingness-Model or fairness fully mediates the relationship between undeservingness and unacceptability. Both explanations imply that participants deemed PCE unacceptable because they judged it to be unfair. We conclude that concerns about unfairness play a crucial role in the subjective unacceptability of PCE and discuss the implications of our approach for the further investigation of the psychology of PCE.

Keywords: cognitive enhancement, neuroenhancement, brain doping, drugs, fairness, cheating, moral judgments

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INTRODUCTION

Pharmacological Cognitive Enhancement and Its Perceived Unacceptability

There are a number of means to enhance cognitive capacities beyond what is usually seen as compensation for an impairment. Nutrition and physical exercise improve cognitive functioning in healthy people across different domains (e.g., Dresler et al., 2013), whilst commonplace stimulants such as caffeine temporarily boost functions like alertness and concentration (e.g., Einöther and Giesbrecht, 2013). Use of these techniques is uncontroversial. Far more controversial is so-called "brain doping," that is the use of "pharmacological interventions that are intended to improve certain mental functions and that go beyond currently accepted medical indications" (Schermer et al., 2009, p. 77).

Such pharmacological cognitive enhancement (PCE) may be achieved through the use of psychostimulants like methylphenidate (e.g., Ritalin®) and wakefulness-promoting drugs like modafinil (e.g., Provigil®). Research has demonstrated that these substances can have performance-enhancing effects in healthy individuals, for example by improving memory or attention (for reviews, see Repantis et al., 2010; Battleday and Brem, 2015; Ilieva et al., 2015). However, current PCE cannot enhance performance to more than modest degrees at best, depending on individual baseline performance (Husain and Mehta, 2011; Caviola and Faber, 2015). Some societies have witnessed a rise in the use of PCE (Care Quality Commission, 2013). Prevalence studies and informal polls suggest that at least some members of different groups use pharmacological substances with the goal to enhance their performance, for instance researchers (Maher, 2008), surgeons (Franke et al., 2013), and, across a range of countries, students (e.g., Singh et al., 2014; Maier et al., 2015; Schelle et al., 2015).

Pharmacological cognitive enhancement not only receives significant media attention, but is also intensively researched in a range of academic disciplines. These disciplines share the aim of understanding PCE (and mind-altering technologies in general) better, and helping society to deal with the challenges posed by increasing PCE use (cf. Greely et al., 2008; Smith and Farah, 2011; Sahakian et al., 2015). PCE is a truly interdisciplinary research topic, on which different disciplines can – and probably ought to – collaborate (cf. Hildt and Franke, 2013; Maslen et al., 2015). Neuroscience and the medical sciences investigate the pharmacological effects and potential side-effects of such substances (e.g., Turner et al., 2003). The behavioral and social sciences deal with questions such as what drives individuals to take PCE (e.g., Wolff and Brand, 2013), how members of the general public perceive PCE (e.g., Sattler et al., 2013), and which social consequences these perceptions might entail for users (e.g., Faulmüller et al., 2013). Meanwhile researchers in philosophy and law examine the ethical and legal problems PCE use entails, weigh these against possible benefits, and in some cases derive recommandations for public policy (e.g., Maslen et al., 2014a) and legal regulation (e.g., Goold and Maslen, 2014). In doing so, they rely on empirical research, as both findings on the pharmacological effects of PCE (e.g., Maslen et al., 2014b), as well as the public perception of PCE (e.g., Forlini et al., 2013) are crucial inputs into ethical, legal and policy debates regarding PCE.

Empirical studies on how members of the general public perceive PCE have already uncovered a variety of concerns people have about PCE, for example regarding medical safety (e.g., Scheske and Schnall, 2012) and societal inequality (e.g., Fitz et al., 2013; for a review, see Schelle et al., 2014). The – although often implicit – goal of many of these studies is to better understand one consistent finding, namely that PCE is deemed *morally unacceptable* (cf. Schelle et al., 2014). The judgment that "PCE is morally unacceptable" – henceforth abbreviated as "***Unacceptability***" – is also found in media reports and in much of the normative debate. This article addresses the question: *why* do lay people endorse *Unacceptability*? That is, why do they judge PCE to be morally unacceptable?

The Present Research: Combining Philosophical Rationales and Psychological Explanations

The primary innovation of our contribution is to employ an interdisciplinary perspective that combines normative philosophical and empirical psychological analyses. We propose that this combination provides a fruitful way to deepen understanding of why people generally judge PCE to be morally unacceptable. Philosophers who have explored moral responses to PCE have frequently, amongst other things, been interested in normative rationales, less in psychological explanations. That is, they have often not been asking why, as a matter of fact, people endorse a certain judgment, but why it might be *rational* to endorse it. Thus, no psychological conclusions can be straightforwardly drawn from philosophical work. However, we suggest that philosophical rationales can be useful in generating psychological hypotheses. As shown in the review by Schelle et al. (2014), lay attitudes on PCE tend to coincide with the attitudes of professional philosophers, suggesting that lay attitudes may have partly the same bases as professional philosophical attitudes. In other words, both philosophical rationalizations and lay attitudes might in part be expressions of a common rational thinking process, which philosophers make more explicit than lay people. (It is important to note, however, that intuitive lay judgments on PCE seem not always to be fully rational, Scheske and Schnall, 2012; cf. Caviola et al., 2014). Philosophical rationales for attitudes on PCE could thus be thought of as making explicit the psychological mechanisms that motivate acceptance of these attitudes in both philosophers and lay people, in so far as both groups form these attitudes rationally. Hence, we explore how philosophical rationales may aid psychology in identifying credible explanations for lay endorsement of *Unacceptability*.

We test the role of three judgments in explaining *Unacceptability:* (1) "PCE produces unfair outcomes," henceforth "***Unfairness,***" (2) "achievements realized with the aid of PCE are "hollow achievements" in the sense that they lack (some of their usual) value," henceforth "***Hollowness,***" and (3) "users

of PCE do not deserve their achievements or the material and non-material reward associated with them," henceforth "***Undeservingness.***" Based on philosophical literature we generate two explanatory psychological models which are based on *Unfairness*, *Hollowness*, and *Undeservingness*, and test these against empirical data.

Philosophers have, implicitly or explicitly, endorsed or at least considered not only *Unacceptability*, but also *Unfairness*, *Hollowness*, and *Undeservingness*. More importantly, recent applied philosophical work on the ethics of cognitive enhancement has begun to explore the relationships between these views, and related work in theoretical philosophy could be deployed to further develop this understanding. Empirical work, in contrast, has consistently shown that lay people are concerned about unfairness induced by PCE use (cf. Schelle et al., 2014), but has not tested whether achievements realized with the help of PCE are seen as hollow or as undeserved or investigated the relationships between these views. Hence, it remains unclear precisely which, if any, of the judgments *Unfairness*, *Hollowness*, and *Undeservingness* contribute to lay endorsement of *Unacceptability*. For instance, is the perceived unacceptability of PCE explained by the judgment that it produces unfair outcomes, the judgment that users of cognitive enhancements do not deserve the reward they received, by both, or by neither? In addition, though it is possible that some or all of these judgments *jointly* explain support for *Unacceptability*, it is not clear (I) what relative contribution each judgment makes to this explanation; and (II) how, if at all, they interact. In this paper, we complement existing empirical research on the question of why lay people endorse *Unacceptability* by comparing three different factors (*Unfairness*, *Hollowness*, and *Undeservingness*) with regard to their relative strength in explaining the overall judgment of *Unacceptability*. We build on existing work by examining two judgments (*Hollowness* and *Undeservingness*) that have not previously been empirically investigated and by examining how the three judgments we consider interact with each other.

In sum, in this paper we combine philosophical rationales and psychological explanations to investigate why PCE is judged as morally unacceptable. We first outline two possible rationales for *Unacceptability*, drawing on both applied and theoretical philosophical work. We then offer two psychological models grounded on these rationales—the Unfairness-Undeservingness Model and the Hollowness-Undeservingness Model—and spell out our research questions regarding these models. Next, we describe our methods for testing these two models against empirical psychological data using a regression-based approach, before setting out the results of this testing. Finally, we discuss the implications of our findings for the psychology and philosophy of PCE.

PHILOSOPHICAL RATIONALES

The lay judgment we ultimately wish to explain—*Unacceptability*—holds that PCE is morally unacceptable. This judgment has been endorsed by a number of philosophers, who have considered a wide range of rationales for it. Broadly speaking, these can be divided into three categories: rationales that focus on the *motives* for which PCE is pursued (e.g., Little, 1998; Sandel, 2007), rationales that focus on the *means* by which it is pursued (e.g., The President's Council on Bioethics (U.S.), 2003; Sandel, 2007), and rationales that focus on the *consequences* of pursuing it (e.g., Fukuyama, 2002; Elliott, 2003). In this section, our aim is not to offer a comprehensive review of all these rationales—this would be too ambitious a task (for a review, see Douglas, 2013). Rather, we limit ourselves to outlining rationales that meet two conditions. First, they appeal to one or more of the judgments *Undeservingness*, *Hollowness*, and *Unfairness* outlined above. Second, they are consequence-based, rather than motive- or means- based rationales. Our reason for limiting our discussion to consequence-based rationales is that adherents of a wide range of moral theories can accept such rationales. Almost all moral theories allow that an act or practice can be morally unacceptable because it has, or can be expected to have, bad consequences. By contrast, it is controversial whether an act can be morally unacceptable purely because of the means that it involves or the motives that produced it.[1]

Two prominently discussed rationales meet our two conditions, namely what we call the "objection from fairness" and the "objection from hollow achievements." In what follows, we set out our interpretations of these rationales.

The Objection from Fairness

A number of authors have endorsed, or at least considered, the view that PCE (or enhancement more generally) may be morally unacceptable because it is unfair or, perhaps equivalently, constitutes a form of "cheating" (e.g., Fukuyama, 2002; The President's Council on Bioethics (U.S.), 2003; Rose, 2006; Schermer, 2008). We call this the "objection from fairness." One variant of this objection holds that PCE is *procedurally* unfair: that it involves unfair means. This is a means- rather than consequence-based rationale for *Unacceptability*, and as such we do not discuss it further. A second variant of the objection holds that PCE is *substantively* unfair: that it produces unfair outcomes, as *Unfairness* holds. This variant of the objection is consequence-based, and will be our focus.

[1]Consequentialist moral theories hold that the moral status of an act is determined solely by its consequences (cf. Skorupski, 1995; Sinnott-Armstrong, 2001). On this view, the only reason that an act can be morally unacceptable (or "impermissible" or, simply, "wrong") is that it has or can be expected to have bad consequences, or worse consequences than the alternatives. Deontological and virtue-ethical moral theories, such as those advanced by Immanuel Kant (e.g., 1786/2013) and Aristotle (e.g., trans, 2014) and their respective followers, hold that further considerations may be relevant. On most such theories, an act can be unacceptable even though it produces good (or the best possible) consequences. For instance, on a deontological theory, a good-maximizing act may be unacceptable because it violates someone's rights or breaks the terms of a contract. On a virtue-ethical theory, it may be unacceptable because it is not what a virtuous agent would have done. However, deontological and virtue-ethical theories typically allow that the value of the consequences of an act remain relevant to the moral status of the act, and that an act can in some cases be morally unacceptable because it produces bad consequences which there is a duty not to produce, or which a fully virtuous agent would not produce (cf. Bennett, 1989; Hursthouse, 1991).

Two questions should be asked regarding this variant of the objection from fairness. First, why think that *Unfairness* supports *Unacceptability*? Second, why accept *Unfairness* in the first place?

The answer to the first question is straightforward, though not normally made explicit in the literature on PCE: unfairness is bad, and as noted above, proponents of a range of moral theories can agree that, other things being equal, it is morally unacceptable to produce bad consequences. Why, precisely, unfairness is bad is controversial. Some hold that it is bad *in itself* (e.g., Broome, 1991). Others, would deny this and hold that fairness is only bad if and because it tends to produce further bad consequences, such as reduced individual wellbeing (e.g., Bentham, 1789; Sidgwick, 1893). However, despite this disagreement about *why* unfairness is bad, many agree *that* it is bad, or at least typically so.

The second question—why should we accept *Unfairness*—has caused greater controversy in the ethical debate regarding PCE. On the one hand, it seems "obvious" (The President's Council on Bioethics (U.S.), 2003, p. 280) or at least "intuitive" (Schermer, 2008, p. 88) that some instances of enhancement, including PCE, produce unfairness. On the other hand, doubts can be raised about whether *all* enhancements, or all PCEs, do so (e.g., Savulescu, 2006; Douglas, 2007; Sandel, 2007; Schermer, 2008; Buchanan, 2011a,b; Santoni de Sio et al., in press). Hence, the scope of application of *Unfairness* is contested. There is also disagreement about how to rationalize *Unfairness,* that is about *why* enhancement produces unfairness when it does. One rationale holds that enhancement involves violating social rules or conventions, and it is unfair if individuals acquire reward through rule-violations (cf. Schermer, 2008). As has been noted, however, those who raise fairness-based concerns regarding enhancement frequently take these concerns to apply regardless whether the enhancement in question violates a rule (Schermer, 2008; Savulescu, 2009). For instance, in the context of debate over enhancement in sport, concerns about production of unfairness have often been presented as a *justification* for maintaining prohibitions on enhancement rather than merely a consequence of such prohibitions (e.g., Lenk, 2007; Corlett et al., 2013). Similarly, philosophers concerned about fairness in relation to PCE have not generally restricted their concerns to rule-violating PCE (Fukuyama, 2002; The President's Council on Bioethics (U.S.), 2003). Hence, it seems appropriate to seek a more general rationale for *Unfairness*—one that will apply even in cases where PCE does not involve rule-violation. We suggest that *Undeservingness* might be able to furnish such a rationale (cf. also Schermer, 2008).

As defined above, *Undeservingness* is the judgment that PCE-users do not deserve their achievements or the material (e.g., money) and non-material (e.g., praise) reward associated with them. A number of authors in the debate on the ethics of enhancement have explicitly considered this view (e.g., Mehlman, 2004; Schermer, 2008; Forsberg, 2013), and it has been suggested (Douglas, 2014) that a similar view may be implicit in the work of others (Harris, 2012; Sparrow, 2014). Moreover, opponents of PCE frequently advance claims that can be understood to support *Undeservingness.* For instance, although disputed elsewhere (Douglas, 2014), it is often said that enhancement makes achievements "too easy" or is a way of avoiding effort (Cole-Turner, 2000; Kass, 2003). If true, this might support *Undeservingness*, since exerting effort to overcome difficulties is often thought to confer deservingness (Sadurski, 1985; Milne, 1986; Sorensen, 2010).

The relationship between *Undeservingness* and *Unfairness* has not been explored in detail in the applied philosophical literature on PCE (although cf. Mehlman, 2004; Schermer, 2008); however, it is plausible that the two judgments are normatively connected. One possibility is that *Unfairness* rationalizes *Undeservingness*—that is, because users of PCE are the beneficiaries of unfairness, they do not deserve their reward. Intuitively, people do not deserve unfairly acquired benefits. For instance, when an athlete breaks the rules of a sport and, as a result, wins a competition, we would conclude that she has won unfairly, and this may seem to support the view that she does not *deserve* the reward that come with the victory. This sort of case might seem to suggest that *Unfairness* is normatively more fundamental than *Undeservingness*.

However, theoretical work on the nature of fairness suggests that *Undeservingness* may be the more fundamental judgment: *Undeservingness* may be able to support *Unfairness*.[2] Some prominent theoretical accounts of fairness can be interpreted as holding that fairness, or at least one component of fairness, requires that (material or non-material) reward are distributed across individuals in proportion to the relative degree to which those individuals deserve those reward (Broome, 1990; Feldman, 1995a; Kagan, 2012). In support of this conception of the relationship between fairness and deservingness, consider the following case: Two charity workers undertake humanitarian projects in a poverty-stricken area without any expectation of reward. Their projects are very different in difficulty and scope. One spends several years single-handedly building a hospital that will save thousands of lives over the coming decades. The other spends one afternoon writing letters to local politicians, with the effect that those politicians divert an additional $500 to the provision of affordable pain relief medications. This can be expected to slightly increase the quality of life of each of 100 migraine sufferers for around a week. Intuitively, the first charity worker is more deserving than the second, all else equal, but it would be difficult to rationalize this judgment regarding deservingness by invoking the concept of fairness. On the other hand, the judgment regarding deservingness does seem potentially capable of rationalizing a judgment regarding fairness. Suppose both charity works receive similar levels of praise for their efforts. Intuitively, this is unfair. The first charity working deserves more praise, and it seems unfair if he does not get it.

A similar line of reasoning suggests that *Unfairness* may be able to rationalize *Undeservingness*. Imagine a case in which two scientists, *A* and *B*, make similar and highly significant scientific discoveries. Suppose, however, that *A* made her discovery assisted by PCE which allowed her to work longer hours and more productively, whereas *B* made the discovery

[2] A third possibility is that *Unfairness* and *Undeservingness* are logically connected though neither is more fundamental than the other. For instance, it may be that to say that *X* enjoys an unfair advantage over *Y* is just to say that *A* does not deserve her advantage.

without any such pharmacological assistance. Although we do not ourselves endorse this view, according to *Undeservingness, A* does not deserve her achievement or the praise, academic success, and other reward that accompany it, perhaps because her enhancement allows her to avoid effort, or made her achievement "too easy." On the other hand, it is plausible to assume that *B* does deserve her achievement and associated reward, at least to some extent. However, despite this difference in deservingness, it is likely that these two scientists will receive a similar size of reward for these achievements, at least if *A*'s PCE-use is secret (cf. Faulmüller et al., 2013). Thus, rewards are not distributed in proportion to deservingness, and this, on the present conception of fairness, is unfair. Hence, if (1) *Undeservingness* holds true, and 2) PCE users are rewarded to a similar degree as non-users who achieve similar things, then use of PCE may disrupt fairness.

The Objection from Hollow Achievements

A second candidate rationale for *Unacceptability* invokes *Hollowness*—the claim that achievements realized with the aid of PCE are "hollow achievements" in the sense that they lack (some of their normal) value. This claim, or variants thereof, have been endorsed by a number of authors in the ethical debate on PCE, and enhancement more generally. Juengst (2000) raised the question whether achievements realized via enhancement might be "hollow accomplishments" (p. 39), and The President's Council on Bioethics (U.S.) (2003) claimed that enhancements would undermine the "dignity" (p. 140) of human performance and perhaps render that performance "false" (p. 131), thereby highlighting two specific values (dignity and truth) that enhancements might threaten. In what follows, we focus on the question whether PCE might deprive human achievements of *some* degree of value without taking a stance on what particular kind of value that might be. Following Juengst's terminology, we call this the "objection from hollowness."

As with the objection from fairness, two questions should be asked regarding the objection from hollowness. First, why think that *Hollowness* supports *Unacceptability*? Second, why accept *Hollowness*?

On the first question, why *Hollowness* supports *Unacceptability*, little has been said. However, it is possible to construct a straightforward argument from *Hollowness* to *Unacceptability*. According to *Hollowness*, achievements realized with the aid of PCE lack (some of their normal) value, and this means that pursuit of enhancement has at least one bad consequence: it diminishes at least some forms of value that our achievements might otherwise have had.

More has been said on the second question: *why* accept *Hollowness*? That is, why judge achievements gained with the help of PCE to be hollow achievements? On one view, PCE use can devalue achievements because it corrupts the very purpose of the activity being pursued (e.g., Santoni de Sio et al., in press). In this regard, using an enhancement might – to take an often-cited example – be like completing a marathon with the aid of roller skates (Whitehouse et al., 1997). Some activities (including marathon running) fulfill their purpose only where pursued in a certain kind of way, and in some cases enhancement is incompatible with the required manner of execution. This may be because the activities in question only have value when they manifest a certain kind of human contribution, and the use of enhancement somehow negates the need for any such contribution (Savulescu, 2015). However, as many have noted, not all activities are such that their purpose is undermined when they are pursued with the aid of enhancements (e.g,. Douglas, 2007; Bostrom and Roache, 2008; Roache, 2008; Schermer, 2008; Goodman, 2010; Santoni de Sio et al., in press). Consider landing an airplane or performing a surgical operation. The purpose of these activities is to realize a certain outcome, and the realization of that outcome need not be threatened, and may even be aided, by the use of enhancements (cf. Santoni de Sio et al., 2014). Moreover, activities that would be rendered hollow by very extensive enhancements may not be rendered hollow by more modest ones. For instance, climbing Mount Everest with the aid of a jetpack might render it a hollow achievement, but it is far less clear that climbing with the aid of compressed oxygen, or regular morning coffees, does so. Hence, we think that the present argument cannot support the claim that, generally, achievements realized via PCE are hollow, as some have suggested (e.g., The President's Council on Bioethics (U.S.), 2003). As with *Unfairness*, then, it is desirable to seek a more general rationale for *Hollowness.* And as with *Unfairness,* we suggest that it may be possible to provide such a rationale by using *Undeservingness.*

It is often thought that things that are normally valuable can lack this value when they are not deserved. For instance, pleasure is normally valuable—it normally makes the world a better place when a person experiences pleasure—but some argue that it lacks its normal value when it is not deserved (e.g., Brentano, 1969; Feldman, 1995b). Hence, on this view, pleasure is, other things being equal, less valuable when it is enjoyed by a mass-murderer than when it is enjoyed by an innocent person. Similar thoughts may apply to valuable achievements. It may be that, when achievements are underserved, they lack value. If so, and if PCE undermines deservingness, then achievements realized with the aid of PCE lack value—that is, *Hollowness* holds true.[3]

The Unfairness-Undeservingness Model and the Hollowness-Undeservingness Model

Based on philosophical literature on PCE and on relevant work in moral theory, we have outlined two possible philosophical rationales for *Unacceptability*, that is the claim that PCE is morally unacceptable. According to the first rationale, the objection from fairness, *Unacceptability* can be rationalized by appeal to *Unfairness* and *Undeservingness*. According to the second rationale, the objection from hollowness, *Unacceptability* can be rationalized by appeal to *Hollowness* and *Undeservingness.*

We do not claim that these rationales constitute the only plausible ways of understanding the normative relationships

[3]Again, however, other conceptions of the relationship between *Deservingness* and *Hollowness* are also plausible. For instance, it may be that when a person realizes an achievement without making the appropriate kind of human contribution, this independently renders both the achievement hollow and the achiever undeserving of reward.

between these judgments. For one thing, we have limited ourselves to rationales that can be understood as appealing to bad *consequences* of enhancement, yet we do not rule out the possibility that there are plausible motive- or means-based rationales for *Unacceptability*. For another, there may be consequence-based rationales for *Unacceptability* that we have not considered. We also do not claim that these rationales are in the end successful; indeed, one of us has previously argued against a view similar to *Undeservingness* (Douglas, 2014). However, we do claim the two rationales we have outlined are among the *prima facie* plausible rationales for *Unacceptability*.

Based on the idea that philosophical justifications can form the basis for psychological models, we derive two such models from our theoretical analyses above.

(1) **The Unfairness-Undeservingness Model**: People judge PCE to be unacceptable because they take it to produce unfairness and undermine the degree to which PCE-users deserve their achievement and associated reward. In other words, lay judgments of *Unacceptability* can be jointly explained by *Unfairness* and *Undeservingness*.
(2) **The Hollowness-Undeservingness Model**: People judge PCE to be unacceptable because they find achievements while using PCE hollow and undeserved. In other words, lay judgments of *Unacceptability* can be jointly explained by *Hollowness* and *Undeservingness*.

Note that in our philosophical analysis we discuss different possibilities for causal relationships between *Unfairness* and *Undeservingness* and between *Hollowness* and *Undeservingness*, respectively. For the sake of starting out with parsimonious models for empirical testing, we do not specify causal relationships beyond causes for *Unacceptability* in the psychological part. However, we return to the issue of a causal order of the explanatory variables in the discussion of our empirical results.

Research Questions

The purpose of this paper is to combine normative philosophical and empirical psychological analyses to gain a deeper understanding of why people generally judge PCE to be morally unacceptable. We have derived two philosophically informed models for possible psychological explanations. Based on our theoretical analyses, we formulate the following two research questions.

(I) How well can the judgments *Undeservingness*, *Unfairness*, and *Hollowness* explain *Unacceptability*?
(II) How do these judgments interact, that is, more specifically: which of the two models, the Unfairness-Undeservingness Model or the Hollowness-Undeservingness Model, is better supported by empirical data?

In what follows, we report a test of these philosophy-grounded research questions against empirical data.

PSYCHOLOGICAL EXPLANATIONS

Methods

We tested our research questions by re-analyzing parts of a larger data set we had collected and reported on previously (for details, see Faber et al., 2015a). For 94 participants, this data set contains information on the PCE-related judgments of interest, that is answers on *Undeservingness*, *Unfairness*, *Hollowness*, and *Unacceptability*. (The other participants in the complete data set did not answer questions in relation to cognitive enhancement but on motivation enhancement, so their judgments are not relevant for the present study. Please see Faber et al. (2015a) for further details on this data set.) Hence, our present sample contained 94 U.S. American participants (48% female, mean age 36.9 years[4]), who indicated that they had not previously used PCE. All respondents completed the study online. They gave informed consent to participate and were compensated financially for their participation. This study had been reviewed and approved by the University of Oxford's Medical Sciences Interdivisional Research Ethics Committee.

After answering demographic questions, each participant read a hypothetical scenario about a male student who uses PCE. The part of the scenario describing this use read as follows: "While preparing for his exams, Alex takes medical substances to help him with his work. These pills normally are available on prescription only to treat certain diseases, but Alex knows that they improve brain performance in healthy people. They can make people think faster and more clearly. By taking these "smart pills," he hopes to do better in his exams." After participants had read the scenario, they answered several questions on 7-point Likert-scales (1 = "completely disagree"; 7 = "completely agree"). There was one item each for *Undeservingness* ("If Alex does well in his exams, he deserves praise," reversely coded) and for *Hollowness* ("If Alex does well in his exams, it will be a hollow achievement"). To capture the frequent use of the more familiar concept of "cheating" to express concerns about unfairness, we included two items for *Unfairness*, one referring explicitly to the concept of unfairness ("It will be unfair if Alex does better in his exams than his classmates who don't take the "smart pills") and one to "cheating" ("Taking "smart pills" is cheating"). We used the mean of both items, which were highly correlated [$r(92) = 0.842$, $p < 0.001$], in subsequent analyses. (The pattern of results reported below remains unchanged when only the explicit unfairness item or the "cheating" item is included.) Finally, we assessed participants' global judgment about *Unacceptability* ("Taking medical substances that improve smartness is acceptable"; reversely coded). (For further questions asked that are not relevant for this re-analysis and, hence, not reported below, see Faber et al., 2015a.)

[4]Our participants were of mixed gender, age, as well as educational and socioeconomic backgrounds. They all lived in the USA, however, and in this sense our sample is quite restricted. We cannot be sure that our results can be generalized to people from other cultural backgrounds.

Results

To answer our research questions (I) how well the factors *Undeservingness*, *Unfairness*, and *Hollowness* can explain *Unacceptability*, and (II) which of the two proposed models, the Unfairness-Undeservingness Model and the Hollowness-Undeservingness Model, is better supported by our data, we used a regression-based approach.[5]

Descriptive Statistics

To begin with, to get a sense of the general view of *Unacceptability* in our sample, we performed a descriptive analysis. This analysis showed that the mean level of agreement that PCE is unacceptable was 4.70 ($SD = 1.72$); the median agreement was scale point 5 ("somewhat agree"). 58.6% of participants agreed (between strongly and somewhat) to *Unacceptability*, while 30.9% disagreed (between strongly and somewhat). The remaining 10.6% were undecided. Hence, in line with previous findings on non-users, participants in our sample on average exhibited support for *Unacceptability*, although there was a considerable variance in this view.

Similarly, we looked at the descriptive statistics for *Unfairness, Hollowness*, and *Undeservingness*. The mean level of agreement for *Unfairness* was 4.70 ($SD = 1.76$), and the median 5. The percentage of participants agreeing to *Unfairness* was 59.6%, and 27.7% disagreed. For *Hollowness*, the mean was 4.15 ($SD = 1.79$), and the median was 4. 45.7% of participants agreed to *Hollowness*, and 41.5% disagreed. For *Undeservingness*, the mean was 3.76 ($SD = 1.61$), the median 3. 33.1% agreed with *Undeservingness*, 51.1% disagreed. Hence, while the participants in our sample judged PCE as unfair on average, they were divided on the view whether its use makes achievements hollow, and overall did not agree with the claim that achievements gained with PCE are generally undeserved.

The Unfairness-Undeservingness Model

We tested the degree to which variations in agreement to *Unfairness* and *Undeservingness* could explain variations in agreement to *Unacceptability*, thereby evaluating the ability of the Unfairness-Undeservingness Model to explain the perceived unacceptability of PCE.

We conducted a linear regression analysis with *Unacceptability* as dependent variable and *Unfairness* and *Undeservingness* as predictors. Our two predictors explained a significant amount of the variance in the dependent variable [$F(2,91) = 27.80$, $p < 0.001$, $R^2 = 0.379$, $R^2_{adjusted} = 0.366$]. However, in this regression only *Unfairness* was a significant predictor of *Unacceptability* [$\beta = 0.48$, $t(91) = 3.72$, $p < 0.001$], while *Undeservingness* had no significant explanatory power beyond *Unacceptability* [$\beta = 0.16$, $t(91) = 1.27$, $p = 0.208$]. (*Unfairness* and *Undeservingness* were significantly correlated [$r(92) = 0.769, p < 0.001$], but multi-collinearity statistics showed no reason for concern in our data for this regression analysis (*Unfairness*: Tolerance = 0.409, VIF = 2.446; *Undeservingness*: Tolerance = 0.409, VIF = 2.446).

In sum, while the Unfairness-Undeservingness Model can account for about 38% of the variance in *Unacceptability* judgments, its explanatory power is mainly driven by *Unfairness*.

The Hollowness-Undeservingness Model

Analogously to the calculations for the Unfairness-Undeservingness Model, we tested the plausibility of the Hollowness-Undeservingness Model in explaining *Unacceptability*.

A linear regression analysis with *Unacceptability* as dependent variable and *Hollowness* and *Undeservingness* as predictors showed that the two predictors significantly explained the dependent variable [$F(2,91) = 22.72$, $p < 0.001$, $R^2 = 0.333$, $R^2_{adjusted} = 0.318$]. In this regression, *Hollowness* was a significant predictor of *Unacceptability* [$\beta = 0.35$, $t(91) = 2.57$, $p = 0.012$], and *Undeservingness* had marginally significant explanatory power [$\beta = 0.26$, $t(91) = 1.89$, $p = 0.062$]. (*Hollowness* and *Undeservingness* were significantly correlated [$r(92) = 0.781, p < 0.001$], but multi-collinearity statistics showed no reason for concern regarding the reliability of our data (*Hollowness*: Tolerance = 0.390, VIF = 2.564; *Undeservingness*: Tolerance = 0.390, VIF = 2.564).

In sum, when regarded on its own (i.e., not in comparison to the Unfairness-Undeservingness Model), the Hollowness-Undeservingness Model explains about 33% of *Unacceptability*, with the influence of *Undeservingness* being only marginally significant.

Comparing the Unfairness-Undeservingness Model and the Hollowness-Undeservingness Model

In a further step, we compared the Hollowness-Undeservingness Model to the Unfairness-Undeservingness Model, looking at whether the former has any power in explaining *Unacceptability* beyond the Unfairness-Undeservingness Model.

We used all three factors *Unfairness, Hollowness,* and *Undeservingness*, as predictors in a linear regression with *Unacceptability* as dependent variable. We found that *Hollowness* as an additional predictor only added 1.2% to the explanatory power of the Unfairness-Undeservingness Model, which is a non-significant change [$F(1,90) = 1.73$, $p = 0.193$, $R^2 = 0.391$, $R^2_{adjusted} = 0.371$]. Correspondingly, with all three predictors in the regression analysis, only *Unfairness* had a significant influence on *Unacceptability* [$\beta = 0.41$, $t(90) = 2.93$, $p = 0.004$], while both *Undeservingness* [$\beta = 0.07$, $t(90) = 0.50$, $p = 0.662$] and *Hollowness* [$\beta = 0.19$, $t(91) = 1.31$, $p = 0.193$] had none. Again, *Hollowness* was significantly correlated with both *Undeservingness* [$r(92) = 0.781$, $p < 0.001$] and *Unfairness* [$r(92) = 0.757$, $p < 0.001$], but collinearity statistics seemed unproblematic (*Unfairness*: Tolerance = 0.346, VIF = 2.888; *Hollowness*: Tolerance = 0.330, VIF = 3.027; *Undeservingness*: Tolerance = 0.316, VIF = 3.164).

This model comparison reveals the importance of *Unfairness* in explaining *Unacceptability*. Both *Hollowness* [$\beta = 0.55$, $t(92) = 6.38$, $p = 0.001$] and *Undeservingness* [$\beta = 0.53$, $t(92) = 6.05$, $p < 0.001$] are significantly associated with

[5]Using regression analyses seemed most appropriate to us given our specific research questions, but also in light of the ongoing debate on the statistical (in)appropriateness of dichotomizing continuous variables via median splits to use ANOVAs (e.g., Rucker et al., 2015).

Unacceptability when considered on their own, that is, as sole predictors. As soon as *Unfairness* is taken into account, however, they do not show any additional power in explaining *Unacceptability*. Put differently, while all three factors *Unfairness*, *Hollowness*, and *Undeservingness* jointly can explain about 39% of *Unacceptability*, *Unfairness* alone already explains about 36% [$F(1,92) = 53.64$, $p < 0.001$, $R^2 = 0.361$, $R^2_{adjusted} = 0.361$]. This 2.3% improvement in explanation *Hollowness* and *Undeservingness* can bring is statistically insignificant ($p = 0.193$, as reported above).

In sum, this analysis showed that the Unfairness-Undeservingness Model is superior to the Hollowness-Undeservingness Model in explaining *Unacceptability*, and that this superiority is driven by *Unfairness*. Amongst the three predictors *Unfairness*, *Hollowness*, and *Undeservingness*, *Unfairness* is the only one making a contribution in explaining *Unacceptability* beyond the two others.

DISCUSSION

In this paper, we aimed to gain a deeper understanding of why people generally endorse *Unacceptability*, that is judge PCE as morally unacceptable. For that, we combined normative philosophical and empirical psychological analyses.

The Central Role of Unfairness in Explaining the Unacceptability of PCE

Based on philosophical literature, we argued that three judgments could be deployed to normatively rationalize *Unacceptability*, namely *Unfairness* (the idea that PCE produces unfair outcomes), *Hollowness* (the idea that achievements gained with PCE are hollow achievements), and *Undeservingness* (the idea that users of PCE are less deserving of reward). We developed philosophical rationales that combined these three judgments in different ways and, based on these rationales, proposed two psychological models that could potentially explain why lay people[4] endorse *Unacceptability*. The Unfairness-Undeservingness Model holds that judgments of *Unacceptability* can be jointly explained by *Unfairness* and *Undeservingness*, and the Hollowness-Undeservingness Model holds that judgments of *Unacceptability* can be jointly explained by *Hollowness* and *Undeservingness*. We formulated two research questions: (I) How well can *Undeservingness*, *Unfairness*, and *Hollowness* can explain *Unacceptability*? And (II) is the Unfairness-Undeservingness Model or the Hollowness-Undeservingness Model better supported by empirical data?

We then tested these two research questions in a sample of lay people who indicated that they had not previously used PCE, using a regression-based approach. Descriptively, while participants tended to agree with the overall statements that PCE is unacceptable (*Unacceptability*) and with the claim that it is unfair (*Unfairness*), they were divided on the question whether it leads to achievements being hollow (*Hollowness*), and, on average, they tended to disagree with the idea that achievements gained with PCE are undeserved (*Undeservingness*).

With regards to our first research question, we found that *Unfairness* was clearly the strongest predictor of *Unacceptability,* explaining about 36% of the variance in *Unacceptability* judgments. While the two remaining judgments, *Hollowness* and *Undeservingness*, were also able to significantly predict *Unacceptability* when considered as sole predictors, they had no significant influence over and above *Unfairness*. All three predictors combined explained about 39% of variance. In other words, although people who judge PCE to be unacceptable also judge accomplishments gained with help of PCE to be undeserved and these achievements to be hollow, the two latter factors seem not to be necessary to explain why people endorse *Unacceptability*. All they can contribute to the explanation is just as well explained by *Unfairness* alone. Concerns about unfairness, on the other hand, seem to be central in understanding why PCE is judged as unacceptable.

With regards to our second research question, we consequently found that the Unfairness-Undeservingness Model was superior to the Hollowness-Undeservingness Model in explaining *Unacceptability*. While, again, the Hollowness-Undeservingness Model appeared to well explain *Unacceptability* when regarded on its own, a direct comparison to the Unfairness-Undeservingness Model showed that it did not make any contribution to understanding why PCE is judged as unacceptable beyond what we gain from the Unfairness-Undeservingness Model. Hence, if we are to accept one of these models, we should accept the Unfairness-Undeservingness Model.

Importantly, however, in the Undeservingness-Unfairness Model, *Unfairness* was the only predictor to make a significant contribution in explaining *Unacceptability*, while *Undeservingness* was not. What implications does this fact have for the Unfairness-Undeservingness Model?

An "Unfairness Model" or *Unfairness* as Mediating Variable?

When we proposed the Unfairness-Undeservingness Model, we hypothesized that "people find PCE unacceptable because they take it to produce unfairness and undermine the degree to which the PCE-user deserves her achievement and associated reward. In other words, lay judgments of *Unacceptability* can be jointly explained by *Unfairness* and *Undeservingness*." We found, however, that when we have knowledge about *Unfairness*, we do not need *Undeservingness* to explain *Unacceptability*. There seem to be two plausible possibilities of how this can be interpreted. It could be taken to support either a single-factor "Unfairness Model," or the view that *Unfairness* acts as the mediating variable within the Unfairness-Undeservingness Model.

The straight-forward conclusion from our findings would be to propose a model we could call the "Unfairness Model." An ideal model is one that offers a good trade-off between parsimoniousness and explanatory power. As *Unfairness* alone explains *Unacceptability* just as well as the Unfairness-Undeservingness Model, it seems appropriate to just reject *Undeservingness* and to propose a model that is based solely on *Unfairness*. This Unfairness Model could, of course, not fully explain why people judge PCE as morally unacceptable,

but it could explain around 36% of variance in *Unacceptability* judgments, which is a considerable amount. Proposing such an Unfairness Model would imply that *Undeservingness* (and also *Hollowness*) are purely epiphenomenal. That is, people find PCE morally unacceptable because they find it unfair. And, when they find it unfair, then they judge achievements realized with it to also be undeserved (and hollow). This would be consistent with the view that *Unfairness* may rationalize *Undeservingness*, rather than the reverse (cf. section The Objection from Fairness).

There is, however, a second possibility that is consistent with our data. The Unfairness-Undeservingness Model could still be a plausible model, with the relationship between *Undeservingness* and *Unacceptability* being mediated by *Unfairness*. As described above, our original version of the Unfairness-Undeservingness Model proposed that "judgments of *Unacceptability* can be jointly explained by *Unfairness* and *Undeservingness*." While it seems that "jointly" is not correct (as Undeservingness doesn't add anything to this joint explanation), it might be that *Undeservingness* influences *Unacceptability* via *Unfairness*. This would imply that people find PCE unacceptable *because* they find it unfair, and they find it unfair *because* they find achievements realized with it undeserved. Such a causal chain would be in line both with our data and with philosophical considerations. While we find *Undeservingness* to be a significant predictor of *Unacceptability,* this relationship breaks down as soon as we add *Unfairness* as a second predictor. If, statistically, *Unfairness* were a full mediator of the relationship between *Undeservingness* and *Unacceptability*, we would expect such a result. Moreover, while no causal order between the variables *Unfairness* and *Undeservingness* has been assumed in our psychological model, it has been implicit in our philosophical rationales: in the section on "the objection from fairness," we suggested that *Undeservingness* may rationalize *Unfairness* which in turn may rationalize *Unacceptability*. Hence, our philosophical analysis suggests a causal chain leading from *Undeservingness* over *Unfairness* to *Unacceptability*.

Unfortunately, based on our analyses we cannot assess which of the above possibilities (a single-factor Unfairness Model or *Unfairness* as the mediating variable in the Unfairness-Undeservingness Model) is true. Path analyses could give a good indication in larger samples, and controlled experiments could provide strong conclusions. We hope that future research will shed further light on the relationship between *Undeservingness* and *Unfairness*.

Importantly, however, both possibilities have at their core the same conclusion, namely that *Unfairness* plays a central role in explaining *Unacceptability*, and that we would need to understand why people find PCE unfair if we want to understand why they find it morally unacceptable. Or, put differently, it might well be that a lot of support for the view that PCE is unacceptable would dissolve if PCE was seen as fair. And indeed, concerns about the unfairness of PCE loom large in both the normative debate (e.g., Fukuyama, 2002; The President's Council on Bioethics (U.S.), 2003; Gazzaniga, 2006; Rose, 2006) and lay people's concerns (e.g., Forlini and Racine, 2012; Scheske and Schnall, 2012; Bossaer et al., 2013; Dubljevic et al., 2014; Santoni de Sio et al., in press for a review, see Schelle et al., 2014, p. 8–11). However, again, to date we cannot be certain what the *causal* relationship between *Unfairness* and *Unacceptability* is. So while PCE could be seen as unacceptable *because* it is seen as unfair, it might also be the other way around (PCE may be seen as unfair because seen as unacceptable), or bi-directional.

Understanding the Psychology of PCE

The approach followed in this paper had two core elements. First, we took an interdisciplinary stance by combining normative philosophical and empirical psychological analyses. Second, we tried to shed light on how different normative judgments on PCE are related to each other psychologically. We hope that our approach has not only helped to advance research on the specific question why PCE is generally found unacceptable, but also to illustrate how philosophical analyses can be helpful in understanding the psychology of PCE.

With regards to interdisciplinarity, we hope to have shown how hypotheses derived from philosophical reasoning can serve as guideline about which psychological relationships are fruitful for testing. It would also be interesting, we think, to explore the reverse strategy, that is to use psychological findings to generate philosophical "hypotheses" than can be tested by normative or conceptual analyses. It might, for example, be worthwhile for philosophers to consider whether *Undeservingness* and *Hollowness* could be normatively epiphenomenal, in the sense that they are implications of *Unfairness* but play no role in the rationalization of *Unacceptability* by *Unfairness*.

With regards to our aim to test relations between different judgments on PCE, we think that this is not only worthwhile, but necessary both from an academic and a practical perspective. When we want to understand the psychology of cognitive enhancement, that is how human beings react to PCE and other mind-altering technologies, we need to gain more than a list of reactions these technologies evoke. Rather, we need to know which reactions are cause, and which are consequence; which are central and which are epiphenomenal.

Understanding the psychology of PCE, in turn, is necessary to estimate the non-pharmacological consequences of PCE use. Psychological reactions based on subjective judgments about PCE can be powerful. For instance, people tend to subjectively judge PCE as more effective than it actually is (Ilieva et al., 2013) and some employ it to cope with elevated stress (e.g., Wiegel et al., 2015). However, consuming PCE seems to be detrimental to reducing stress, but on the contrary weakens the protective effect of internal personal resources against burnout (Wolff et al., 2014). Moreover, it has been argued that the prevalent negative judgments of others regarding PCE can cause considerable psychological costs for users (for example reduced self-esteem; Faulmüller et al., 2013).

Increased understanding of psychological processes is also crucial for assessing the consequences PCE has beyond individual users. Current pharmacological research on the effectiveness of PCE substances measures how they influence participants' individual performance. Based on such research, it has been argued that the use of PCE would also be beneficial on a societal level, for example, because enhancements will increase human productivity, resulting in general economic benefits through

either greater availability of goods or lower prices (Bostrom and Ord, 2006; Buchanan, 2008, 2011a,b). However, a psychological understanding of normative attitudes to enhancement could complicate this picture. Employing a psychological perspective, it has been illustrated that the effect of PCE on an individual's performance can be increased, but also be reduced, completely eliminated or even reversed at a group level (Faber et al., 2015b): The effectiveness of PCE in improving group performance depends on the psychological processes within the group, which, in turn, is guided by the subjective judgments the group members make about PCE. If, for example, group members who do not use PCE form negative attitudes to PCE-users, this can lead to these two parties not interacting efficiently and not functioning well as a performance group. In such a case, even though a PCE substance is an enhancement of individual performance (for pharmacological reasons), it could even act as an impairment for a group (for psychological reasons). Therefore, subjective judgments about PCE can determine the performance benefits groups can – or cannot – draw from PCE.

Hence, if we want to know how PCE affects us as a society, we need to understand not only the pharmacology, but also the psychology associated with such technologies. We think that both employing an interdisciplinary perspective and investigating the relationships between judgments on PCE is fruitful to understand this psychology. At present, research on the public perception of PCE and its consequences is still in its infancy. We hope that in the near future we will have a more comprehensive and coherent picture of the psychology of PCE – both for our academic understanding of human enhancement and to assist policy making.

AUTHOR CONTRIBUTIONS

NF and TD developed the models. NF analyzed the data. NF, JS, and TD wrote the paper.

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Pharmacological Neuroenhancement in the Field of Economics—Poll Results from an Online Survey

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Introduction: The use of over-the-counter, prescription, and illicit drugs to increase attention, concentration, or memory—often called (pharmacological) neuroenhancement—shows a broad range of prevalence rates among students. However, very little data is available on neuroenhancement among employed persons. The aim of this study was to provide first data on substance use for neuroenhancement among readers of the German "Handelsblatt" coming from the field of economics.

Methods: Readers of the online edition of the Handelsblatt, a leading print and online medium for the field of economics, were invited to participate in a survey via a link on the journal homepage to complete a web-based questionnaire. Within the questionnaire, participants were asked for their gender, current age, current professional status, hours of work per week, prevalence rates of substance use for the purpose of neuroenhancement as well as for reasons of its use. Binary regression analyses with stepwise forward selection were used to predict the dependent variables "use of illicit and prescription drugs for neuroenhancement" (yes/no), "use of over-the-counter drugs for neuroenhancement" (yes/no), and "use of any drug for neuroenhancement" (yes/no).

Results: A total of 1021 participants completed the anonymous survey. Lifetime prevalence for the use of any drug for neuroenhancement was 88.0% and for the use of illicit and prescription drugs for neuroenhancement 19.0%. Reasons and situations that predicted neuroenhancement with illicit and prescription drugs were "curiosity," "to enhance mood," "for a confident appearance," "stress/pressure to perform," and "deadline pressure."

Discussion: The study shows that neuroenhancement with drugs is a widespread and frequent phenomenon among people belonging to the professional field of economics. Given in the literature that the use of drugs, especially prescription, and illicit drugs, may be associated with side effects, the high epidemic of drug use for neuroenhancement also shown in the present paper underlines the new public health concern of neuroenhancement.

Keywords: neuroenhancement, drugs, misuse, economy, addiction, survey

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INTRODUCTION

A 2008 publication of survey results about the use of cognition-enhancing drugs among the readers of *Nature* introduced a phenomenon called neuroenhancement to the scientific world (Maher, 2008). Pharmacological neuroenhancement is frequently defined as the use of any drug to enhance vigilance, attention, concentration, memory, mood, self-confidence, or self-expression without medical need (Greely et al., 2008; Franke et al., 2014). Different terms have been used such as "pharmaceutical/ pharmacological cognitive enhancement," "mood enhancement," "academic performance enhancement," "academic doping," "cosmetic neurology" etc. to describe the above mentioned aim emphasizing the different cognitive and/or non-cognitive domains and contexts of the use (Chatterjee, 2004; Lucke et al., 2011; Partridge et al., 2011; Fond et al., 2015; Franke et al., 2015b; Sahakian and Morein-Zamir, 2015).

The *Nature* poll assessed the use of Ritalin® (methylphenidate, MPH), Provigil® (modafinil), and beta blockers for neuroenhancement and found that one fifth of the 1400 participants had used at least one of these drugs to improve their focus, concentration or memory without medical need. The most popular of the assessed drugs was Ritalin® and the most frequent reason for taking the drugs was to improve concentration (Maher, 2008). However, the online poll was then criticized by some authors in the *Nature* blog e.g., regarding the methodology (e.g., participation bias).

An elaborative systematic review by Wilens and colleagues had already shown a past-year prevalence of 5-35% for the general misuse of stimulants among college students (Wilens et al., 2008). Meanwhile, numerous studies from different countries have examined neuroenhancement among students and shown a broad range of prevalence rates for neuroenhancement (between 1 and 20%), depending on the drugs assessed and the survey methods used (McCabe et al., 2005; Boyd et al., 2006; Teter et al., 2006; Franke et al., 2011a; Dietz et al., 2013a; Maier et al., 2013; Webb et al., 2013). The most recent survey among students "shows that prescription drugs, illicit drugs, and lifestyle drugs are, respectively, used by 1.7, 1.3, and 45.6% of the sample" (Schelle et al., 2015).

Surveys about the use of drugs for neuroenhancement in the workplace are very rare. A recent survey among surgeons by Franke and colleagues found a lifetime prevalence rate of 9% for the use of prescription and illicit drugs, 13% for caffeine tablets, and 24% for caffeinated drinks (which describes the mainly German term "Energy drinks" included in the upper most cases caffeine and taurine, excluding cola drinks; Franke et al., 2013, 2015a). Using a technique for increased confidentiality during the assessment (randomized response technique, RRT Campbell, 1987; Moshagen et al., 2010), the group found a lifetime prevalence rate for prescription and illicit drugs of 20% (Franke et al., 2013). A survey by the German DAK found a lifetime prevalence rate of 3.3% for "neuroenhancement" and 4.7% for "neuroenhancement to increase mood or to reduce anxiety and nervousness" [Deutsche Angestelltenkrankenkasse (DAK), 2015]. The KOLIBRI study found a last-year prevalence of 1.5% for all prescription drugs (beta-blockers, stimulants, MPH, antidementia drugs, antidepressants, and modafinil) and 1.0% of which was attributed to antidepressants [Robert-Koch-Institut (RKI), 2011]. The most recent survey concerning neuroenhancement in the workplace using an anonymizing technique revealed a 12-month prevalence rate of 15.4% for the use of prescription drugs among 1186 employed persons (mostly teachers) in Jordan (Wolff et al., 2015). Furthermore, a survey study by Franke and colleagues in 3300 surgeons showed that reducing fatigue, working the night shift and excessive work hours were frequent reasons for using PN substances. This seems to show that coping with unfavorable working conditions such as "stress" are important reasons for using PN drugs (Franke et al., 2013, 2015a). Among students, stress periods in the scope of preparation for exams are associated with the use of PN drugs Burgard et al., 2013). However, among teachers, the willingness of using PN drugs was shown to be low (Sattler et al., 2013; Wiegel et al., 2015). The recent DAK study among 5000 employees showed lifetime prevalence rates of 3.3% for "neuroenhancement" and 4.7% for "neuroenhancement to increase mood or to reduce anxiety and nervousness" [Deutsche Angestelltenkrankenkasse (DAK), 2015].

Numerous studies with divergent study designs have been performed with the group of drugs considered to be neuroenhancers (Mehlman, 2004; De Jongh et al., 2008) to assess the efficacy of the candidate drugs (Solomon et al., 2002; Wesensten et al., 2002; Yesavage et al., 2002; Breitenstein et al., 2004; Killgore et al., 2008, 2009). Overall, the group of stimulants—methylxanthines, e.g., caffeine, and amphetamines, e.g., MPH—seems to have broad pro-cognitive effects on simple cognitive domains that can be affected in fatigued persons. Furthermore, some studies indicate pro-cognitive effects on certain higher cognitive domains, such as particular memory domains. In addition, euphoric effects (in the scope of mood neuroenhancement) of amphetamines have to be considered. (Repantis et al., 2010a,b; Kelley et al., 2012; Franke et al., 2014).

The present web-based study design was inspired by the above mentioned *Nature* poll with the aim to raise data from persons who work in the field of economics or economic-related studies. Therefore, the study assessed for the first time the use of potential neuroenhancers based on an online poll posted on the homepage of the "Handelsblatt" in order to capture data of their readers.

We hypothesized that the prevalence rates of drug use for neuroenhancement within the field of economics as well as associated factors would be similar to previous studies in students, physicians and scientists.

MATERIALS AND METHODS

The present survey was designed on the basis of the *Nature* poll by Brendan Maher (Maher, 2008). We chose to advertise the survey in the German "*Handelsblatt*," a print and online medium for people working in the field of economics. The *Handelsblatt*, which until 2005 was part of the company that publishes the *Wall Street Journal* in the US, is the leading economics journal

in German-speaking countries; its print run in 2014 was 120,000 and in Germany it is the most cited print medium for economics (Handelsblatt). Readers of the online edition of the *Handelsblatt* were invited to participate in the present survey via a link on the homepage of the journal (www.Handelsblatt.com)[1].

Data Acquisition

To ensure a high degree of privacy and anonymity, the survey was designed as an online poll with eight closed questions about participants' characteristics and their patterns of drug use for neuroenhancement. The survey was open for participation during the last 2 weeks of December 2014. Before starting the survey, readers read a short introductory paragraph that introduced them to the topic of neuroenhancement and explained the survey. Then, after answering questions about their gender, current age, current professional status, and hours of work per week, participants were asked if they would at all consider using (a) legal over-the-counter drugs (OTC drugs) (b) prescription drugs, or (c) illicit drugs for neuroenhancement or (d) no drugs for enhancement at all. Directly afterwards, participants were asked to indicate any substances they had already used for neuroenhancement by completing a table that listed OTC drugs and prescription and illicit drugs as well as drinks known to be frequently used for neuroenhancement by students (Mehlman, 2004; De Jongh et al., 2008; Franke et al., 2011b, 2014; Dietz et al., 2013b; Schelle et al., 2015) and surgeons (Franke et al., 2013, 2015a): coffee, energy/caffeinated drinks, caffeine tablets, cola drinks, Ginkgo biloba, Ritalin®, Adderall®, modafinil, ecstasy, ephedrine, cocaine, crystal meth, illicit amphetamines, and antidepressants. Subsequently, participants were asked which of the following situations and reasons were associated with their use of the aforementioned drug or drugs for neuroenhancement (multiple responses were possible): (a) curiosity, (b) stress/pressure to perform, (c) tiredness, (d) to enhance mood, (e) for a confident appearance, (f) deadline pressure, (g) other; these categories were identified in previous studies in students as reasons and situations commonly associated with the use of drugs for neuroenhancement.

In order to exclude from further analysis participants who used certain prescription drugs to treat a disease, participants were asked if they suffered from attention-deficit-hyperactivity disorder (ADHD) or depression. Participants who stated to "have been diagnosed" with ADHD or depression were excluded.

Data Analysis

Data were collected in a database connected directly to the survey questionnaire. Statistical analyses were performed with SPSS for Windows, version 22.0. Binary regression analysis with stepwise forward selection was used to predict the dependent variables "use of illicit and prescription drugs for neuroenhancement" (yes/no), "use of OTC drugs for neuroenhancement" (yes/no), and "use of any drug for neuroenhancement" (yes/no). Continuous variables (age, hours of work per week) were dichotomized by mean. Results are given as means and standard deviations (SD), prevalence rates (%), or odds ratios (OR) with Clopper-Pearson confidence intervals (95% CI) and *p*-values.

[1]According to a personal communication from the Handelsblatt and www.Handelsblatt.com (accessed in april 2015) and www.ivw.eu (accessed in april 2015).

Ethics Statement

The study was performed according to the Declaration of Helsinki. Participants gave informed consent by clicking on a button after reading the short introductory paragraph and by pressing the button "done" at the end of the survey. The study was approved by the responsible ethics committee (Greifswald; approval no. BB 095/14).

RESULTS

In total, 1021 readers of the journal *Handelsblatt* participated in the survey. Among the participants, 6.6% ($n = 67$) reported to have been diagnosed with ADHD or depression and had to be excluded from further analysis. Therefore, the data of 954 participants were analyzed. Most of the participants were male (82.7%), with a mean age of 36.3 years. Approximately one-third of the participants rated themselves as belonging to "middle management" (32.4%). Participants worked aF mean of 48.7 h per week. **Table 1** gives a detailed description of participant characteristics.

Regarding the question of whether the participants would consider using any substance for neuroenhancement, 40.0% ($n = 372$) answered "yes, an OTC substance," 12.6% ($n = 117$) answered "yes, a prescription drug" and 8.3% ($n = 77$) answered "yes, an illicit drug."

Among all participants, 88.0% ($n = 831$) had used one of the listed substances (see Materials and Methods Section) for neuroenhancement purposes at least once in their life (lifetime prevalence): lifetime prevalence was 87.5% ($n = 824$) for the use of any OTC drug for neuroenhancement and 19.0% ($n = 171$) for the use of any prescription or illicit drug for neuroenhancement. Among the group of OTC drugs and drinks the most commonly used substance was coffee (lifetime prevalence: 77.1%, $n = 723$),

TABLE 1 | Basic characteristics of the survey participants.

Characteristic	Frequency or range, mean and standard deviation of characteristic among participants ($N = 954$)
Gender	82.7% male ($n = 767$)
	17.3% female ($n = 160$)
Age, y (mean, SD)	17–71 (36.3, 11.2)
CURRENT PROFESSION	
"Simple" employee	28.8% ($n = 270$)
Middle management	32.4% ($n = 304$)
Top management	9.6% ($n = 90$)
Freelancer	12.5% ($n = 117$)
Public official	1.5% ($n = 14$)
Student studying economics	15.0% ($n = 141$)
Not working	0.3% ($n = 3$)
Hours of work per week, h (mean, SD)	4–100 (48.7, 11.1)

followed by cola drinks (Coca-Cola®, etc.; lifetime prevalence: 56.6%, $n = 521$; see **Table 2**). The most frequently used drugs among the group of prescription and illicit drugs were antidepressants, with a lifetime prevalence of 7.2% ($n = 65$) and a period prevalence rate in the last month of 2.0% ($n = 18$); during the last month only cocaine was used more frequently (2.3%, $n = 20$; **Table 2**). For more detailed information about prevalence rates, see **Table 2**.

The most frequently mentioned situations or reasons associated with using any drug for neuroenhancement including OTC and prescription and illicit drugs were "tiredness" (79.4%, $n = 533$), "stress/pressure to perform" (41.7%, $n = 280$), and "to enhance mood" (22.2%, $n = 149$). The rates for "deadline pressure," "curiosity," "for a confident appearance," and "others" were 17.3% ($n = 116$), 12.2% ($n = 82$), 11.8% ($n = 79$), and 11.5% ($n = 77$), respectively; **Table 3** gives further details about situations or reasons associated with the use of OTC drugs and prescription and illicit drugs.

Binary logistic regression revealed five independent variables that predict the use of illicit and prescription drugs for neuroenhancement: "curiosity," "stress/pressure to perform," "to enhance mood," "for a confident appearance," and "deadline pressure" (see **Table 4**). The dichotomized independent variables "age" and "hours of work per week" as well as each of the items "current profession," "using OTC drugs for neuroenhancement," "gender," and "tiredness" did not significantly predict the use of illicit and prescription drugs for neuroenhancement. Only two independent predictor variables, "tiredness" and "stress/ pressure to perform," were found for OTC drug use for neuroenhancement and for the use of any substance for neuroenhancement (including OTC, illicit and prescription drugs), respectively (see **Table 4**).

The areas under the receiving operation curve (ROC) of the overall regression models were 77.2% for "use of illicit and prescription drugs for neuroenhancement," 85.5% for "use of OTC drugs for neuroenhancement," and

TABLE 2 | Prevalence rates for use of substances for neuroenhancement among survey participants ($N = 954$).

Use of any surveyed substance	Never used	Used			
		Total responses	Within the last month	Within the last 12 months	More than 12 months ago
OTC DRUGS/DRINKS					
Coffee	22.9%	77.1%	43.5%	7.6%	26.0%
	($n = 215$)	($n = 723$)	($n = 408$)	($n = 71$)	($n = 244$)
Energy/caffeinated drinks	53.3%	46.7%	21.0%	13.6%	12.0%
	($n = 489$)	($n = 428$)	($n = 193$)	($n = 125$)	($n = 110$)
Caffeine tablets	74.9%	25.1%	5.8%	6.3%	13.0%
	($n = 669$)	($n = 224$)	($n = 52$)	($n = 56$)	($n = 116$)
Cola drinks (e.g., Coca-Cola, etc.)	43.4%	56.6%	31.2%	11.5%	13.9%
	($n = 399$)	($n = 521$)	($n = 287$)	($n = 106$)	($n = 128$)
Ginkgo biloba	89.4%	10.6%	2.7%	3.7%	4.1%
	($n = 788$)	($n = 93$)	($n = 24$)	($n = 33$)	($n = 36$)
PRESCRIPTION AND ILLICIT DRUGS					
Ritalin	94.9%	5.1%	1.5%	1.9%	1.7%
	($n = 852$)	($n = 45$)	($n = 13$)	($n = 17$)	($n = 15$)
Adderall	96.7%	3.3%	0.8%	0.8%	1.7%
	($n = 853$)	($n = 29$)	($n = 7$)	($n = 7$)	($n = 15$)
Modafinil	97.7%	2.3%	0.9%	0.5%	0.9%
	($n = 857$)	($n = 20$)	($n = 8$)	($n = 4$)	($n = 8$)
Ecstasy	95.6%	4.4%	1.6%	0.9%	1.9%
	($n = 843$)	($n = 39$)	($n = 14$)	($n = 8$)	($n = 17$)
Ephedrine	94.7%	5.3%	1.6%	1.4%	2.3%
	($n = 829$)	($n = 46$)	($n = 14$)	($n = 12$)	($n = 20$)
Cocaine	93.5%	6.5%	2.3%	1.3%	3.0%
	($n = 820$)	($n = 57$)	($n = 20$)	($n = 11$)	($n = 26$)
Crystal meth	98.2%	1.8%	0.6%	0.5%	0.8%
	($n = 857$)	($n = 16$)	($n = 5$)	($n = 4$)	($n = 7$)
Illicit AMPH	93.0%	7.0%	1.9%	1.9%	3.2%
	($n = 826$)	($n = 62$)	($n = 17$)	($n = 17$)	($n = 28$)
Antidepressants	92.8%	7.2%	2.0%	2.5%	2.7%
	($n = 839$)	($n = 65$)	($n = 18$)	($n = 23$)	($n = 24$)

AMPH, amphetamines; "ever," within the last month + within the last 12 months + more than 12 months ago; OTC drugs, over-the-counter drugs.

TABLE 3 | Reasons and situations associated with the use of drugs for neuroenhancement.

	OTC drugs (*N* = 669)	Prescription and illicit drugs (*N* = 155)	OTC drugs + prescription and illicit drugs (*N* = 671)
Curiosity	12.1% (*n* = 81)	31.0% (*n* = 48)	12.2% (*n* = 82)
Stress, pressure to perform	41.7% (*n* = 279)	60.6% (*n* = 94)	41.7% (*n* = 280)
Tiredness	79.4% (*n* = 531)	72.3% (*n* = 112)	79.4% (*n* = 533)
To enhance mood	22.1% (*n* = 148)	45.8% (*n* = 71)	22.2% (*n* = 149)
For a confident appearance	11.7% (*n* = 78)	29.0% (*n* = 45)	11.8% (*n* = 79)
Deadline pressure	17.2% (*n* = 115)	28.4% (*n* = 44)	17.3% (*n* = 116)
Others	11.5% (*n* = 77)	16.8% (*n* = 26)	11.5% (*n* = 77)

OTC drugs, over-the-counter drugs.

TABLE 4 | Predicting factors for the use of substances for neuroenhancement.

Predictor	OR (95% CI)
USE OF ILLICIT AND PRESCRIPTION DRUGS FOR EUROENHANCEMENT	
Curiosity	4.79*** (2.75–8.33)
To enhance mood	2.72*** (1.68–4.42)
For a confident appearance	2.69** (1.47–4.91)
Stress/ pressure to perform	1.83* (1.15–2.91)
Deadline pressure	1.79* (1.03–3.11)
USE OF OTC DRUGS FOR NEUROENHANCEMENT	
Tiredness	22.44*** (4.68–107.64)
Stress/pressure to perform	10.15*** (1.24–83.01)
USE OF ANY SUBSTANCE FOR NEUROENHANCEMENT	
Tiredness	45.24*** (5.46–374.77)
Stress/pressure to perform	9.59*** (1.13–81.12)

Odds ratios for the dependent variables "use of illicit and prescription drugs for neuroenhancement," "use of OTC-drugs for neuroenhancement," and "use of any substance for neuroenhancement" and each predictor variable (stepwise, forward regression). Levels of significance: $p < 0.05$; $p < 0.01$**; $p < 0.001$***; (CI, confidence interval; OR, odds ratio); OTC drugs, over-the-counter drugs.*

88.1% for "use of any substance for neuroenhancement," respectively.

DISCUSSION

This study used an anonymous web-based questionnaire to investigate for the first time the use of drugs for neuroenhancement among the "Handelsblatt" readership working or at least studying in the field of economics. The study shows that the prevalence rates of neuroenhancement in the surveyed participants within the field of economics are similar to those in other highly demanding fields. Although, the associated reasons and situations are somewhat similar, non-cognitive reasons for neuroenhancement are much more important in our participants than among the previously studied groups (students, surgeons).

Among the large number of papers on neuroenhancement, one of the most extensive studies (in 8000 students) found lifetime prevalence rates of 5% for prescription drugs and 5% for so-called "soft enhancement" (use of vitamins, homeopathic drugs, "herbal" substances, caffeine, etc.), i.e., significantly lower rates than that in our study (40.0%; Middendorff et al., 2012).

There is a paucity of data about neuroenhancement among the general population and employed persons in particular. For their 2015 health report, a German health insurance company (DAK) re-assessed a representative panel of 5000 participants aged between 20 and 50 years [Deutsche Angestelltenkrankenkasse (DAK), 2015]. The online study had a response rate of 49.1% and found lifetime prevalence rates of 3.3% for "neuroenhancement" and 4.7% for "neuroenhancement to increase mood or to reduce anxiety and nervousness" [Deutsche Angestelltenkrankenkasse (DAK), 2015]. Cognitive neuroenhancement was more frequent among men, and mood neuroenhancement, as well as reduction of anxiety and nervousness, more frequent among women [Deutsche Angestelltenkrankenkasse (DAK), 2015]. This finding is in contrast to our study results. We found significantly higher prevalence rates and no differences between men and women regarding special patterns of substance use which may be due to the inequal preponderance in our study in contrast to the DAK study. However, in line with the DAK study we found higher prevalence rates for mood neuroenhancement than for cognitive neuroenhancement, which we consider to be one of the most important findings of our study.

The Kolibri study evaluated 6000 participants from the general public and found a last-year prevalence of 1.5% for all prescription drugs (beta-blockers, stimulants, MPH, antidementia drugs, antidepressants and modafinil), 1.0% of which was attributed to antidepressants [Robert-Koch-Institut (RKI), 2011]. The relatively high prevalence rates for the use of potential mood-enhancing substances concur with our findings.

One German web-based study used vignettes to examine the prevalence rate of neuroenhancement among university teachers and their willingness to use drugs for neuroenhancement and found both to be low (Sattler et al., 2013; Wiegel et al., 2015). However, teachers are not comparable with the participants surveyed in this study.

The *Nature* poll mentioned above found a lifetime prevalence rate of 20% for the use of beta-blockers, methylphenidate (MPH; Ritalin®), and modafinil (Maher, 2008) which is nearly the same as that found among the participants of the present survey (19.0% lifetime prevalence rate for prescription and illicit drug use). Ritalin® was the most commonly used drug in the *Nature* poll, and in our study lifetime prevalence rates were highest for illicit amphetamines. Considering that MPH belongs to the group of amphetamines and Ritalin® was the third most frequently used prescription/illicit drug in our survey, the results are again comparable. Beyond the question of the frequency of use for neuroenhancement, Maher found that the most popular

reasons for the use of the three assessed drugs were to improve concentration, improve focus for a specific task, and counteract jetlag (Maher, 2008). Interestingly, these reasons do not overlap with those found in our study, which identified curiosity, mood neuroenhancment, and confident appearance as the three most important reasons for neuroenhancement.

Franke et al. studied 3300 surgeons and found a lifetime prevalence rate for the use of prescription and illicit stimulants of 8.9% when participants completed a direct questioning survey (paper-and-pencil questionnaire) and 19.9% when the specialized anonymizing survey technique RRT was applied (Franke et al., 2013, 2015a). Furthermore, lifetime, past-year, past-month, and past-week prevalence rates for coffee were 66.8, 61.9, 56.9, and 50.5%, for caffeinated drinks 24.2, 15.4, 9.9, and 6.1%, and for caffeine tablets 12.6, 5.9, 4.7, and 3.8%, respectively. Although, prevalence rates for coffee were similar to those in the present study, those for caffeinated/energy drinks and caffeine tablets were significantly lower (Franke et al., 2015a). Prevalence rates for (psycho-) stimulants were higher among surgeons than in our study (Franke et al., 2013).

Among surgeons, reducing fatigue (54.3%), working the night shift (32.2%), and overly long and excessive work hours (31.7%) were the most frequent reasons for using caffeine (Franke et al., 2013). This finding could only be partially confirmed in the present study, which identified tiredness, stress/ pressure to perform, and mood neuroenhancement as the three most important reasons for using caffeine.

When Franke and colleagues compared the use of prescription and illicit drugs by surgeons for cognitive neuroenhancement with the use of antidepressants for mood neuroenhancement, which was a separate category in the study, they found lifetime prevalence rates of 8.9% for the former and only 2.4% for the latter (Franke et al., 2013). Our study found much higher prevalence rates for antidepressant use without medical need (7.2%, $n = 65$), i.e., the rate was three-fold higher among the present participants. The reason for this discrepancy is unclear. Therefore, future studies should address in detail the reasons why participants use drugs for the purpose of neuroenhancement and for mood enhancement.

The question of anonymity and privacy when using a survey about potentially stigmatizing issues is complex. Empirical social science has shown a tendency for people to answer with socially desirable answers when asked about sensitive or stigmatizing issues (e.g., own thievery; Schnell et al., 1992). This aspect is important when asking participants about their use of neuroenhancement drugs which, at least in the case of misusing prescription drugs and using illicit drugs, is potentially punishable. Therefore, other studies using the RRT—which is only one among a variety of techniques for the assessment of socially undesirable behavior (Campbell, 1987; Moshagen et al., 2010; Wolff et al., 2015)—to assess the use of antidepressants among surgeons, found prevalence rates of 19% for cognitive neuroenhancement and 15% for mood neuroenhancement. Prevalence rates for cognitive neuroenhancement are comparable to our results; however, prevalence rates for mood neuroenhancement are considerably higher. Comparable prevalence rates for neuroenhancement may imply that an online poll gives a subjective feeling of anonymity and privacy similar to the RRT, perhaps because (more or less) nobody can trace answers back to the participants.

Taken together, the high discrepancy between the direct questioning and RRT results for antidepressants and the high prevalence rates for the use of antidepressants found in the present study could mean that mood neuroenhancement and not cognitive neuroenhancement is the "core enhancement" phenomenon. Because stimulants also have euphoric effects, they are perhaps being used for both purposes. An as yet underestimated reason could be to feel more self-confident and to enhance mood. Even though this assumption is highly speculative, it is supported by the present study and may therefore warrant further investigation.

In addition to the aspects mentioned above, some factors should be addressed that limit the explanatory power of this study. As with every survey study, one can discuss the suitability of the content and length of the questionnaire and the likelihood of complete participation. Our questionnaire, inspired by the online *Nature* poll (Maher, 2008) was designed to increase the likelihood of participation and the completeness of participants' responses at the expense of losing a large amount of information because of its brevity. Therefore, the authors designed the questionnaire on the basis of the available neuroenhancement literature to be brief but nevertheless informative. A web-based survey has an inherent risk of participation bias because one cannot control for participants' experiences, opinions, personal characteristics, and subjective aims when answering the questions. Nevertheless, we considered such a survey the best way to collect "real life" data and gain insight into the fast-paced field of economics.

The main strength of this study, its high degree of anonymity and privacy, is also the cause of one of its most **limiting factors**, the participation bias. Because the present study was voluntarily conducted as an online poll—to guarantee the highest degree of anonymity and privacy—in the *Handelsblatt*, readers of the online version of this specific journal were able to participate. However, because of the possibility to distribute links via social media networks, it cannot be guaranteed that only readers of the *Handelsblatt* participated. This may explain the fact, that the group of participants is more or less heterogeneous. Means to reduce participation bias and to control for participation (e.g., via participation codes, etc.) leads to reduced anonymity and privacy and were not considered by the authors in order to receive honest answers. This major limitation was of similar concern in the *Nature* poll by Brendan Maher.

Beyond that, the online version is widely read and only ∼1000 individuals participated, which may not be representative of only those working in the field of economics. Furthermore, we have no information about possible specific characteristics of the individuals who did not participate. Therefore, we do not know whether those individuals would have increased or decreased the prevalence rate for neuroenhancement or shown additional predictors. Online surveys cannot control for such a disproportion and response bias.

In sum, the study results presented here show that drug use to increase cognition, enhance mood, improve confidence,

or cope with stress and pressure seems to be a widespread phenomenon within the field of economics. Taken together, the results of this and previous studies indicate that the findings of studies in high school, college, and university students may also be valid in employed persons. Findings in employed persons such as surgeons, individuals working in the professional field of economics, and natural scientists demonstrate that neuroenhancement has become a widespread phenomenon. Both are associated with health concerns, because any (mis-) use of drugs may have adverse effects on mental and physical health. For example, any stimulant is associated with the risk of cardiovascular events, hypertonia, tachycardia, and even sudden cardiac death (e.g., Kumar, 2008; Ali et al., 2015; Vetter et al., 2015). Such events may be more frequent when drugs are misused without a physicians' prescription or are mixed with other drugs. Additionally, drug misuse can lead to addiction and be a gateway for the use of other—more harmful or illicit—drugs (Kandel, 2002; Dietz et al., 2013b, 2016). Taking these negative aspects together and considering the high prevalence rates of drug use for neuroenhancement, we think that the creation of prevention programs and related educational material is of great public health relevance. A large journal with an online version like the *Handelsblatt*, which is read by a potential at-risk population, could be used to spread information and material about such programs. Additionally, the predictors for drug use for neuroenhancement identified in the present study may help to create well-directed prevention programs and education material tailored more closely to individual needs. As the metric scaled variables in the present study were dichotomized for analyses, one implication for future studies would be to provide more individual profiles of drug users, addressing more specific demographic characteristics, rather than the dichotomized method used in the current study.

AUTHOR CONTRIBUTIONS

AF made substantial contributions to the conception and design of the study, the data acquisition, analysis, and interpretation of data, and the preparation of the manuscript. MS made substantial contributions to the interpretation of data and the preparation of the manuscript. PD made substantial contributions to the analysis and interpretation of data and the preparation of the manuscript. All authors proofread and accepted the final version of the manuscript.

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Associations Between the Big Five Personality Traits and the Non-Medical Use of Prescription Drugs for Cognitive Enhancement

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While the number of studies of the non-medical use of prescription drugs to augment cognitive functions is growing steadily, psychological factors that can potentially help explain variance in such pharmaceutical cognitive enhancement (CE) behavior are often neglected in research. This study investigates the association between the Big Five personality traits and a retrospective (prior CE-drug use) as well as a prospective (willingness to use CE drugs) measure of taking prescription drugs with the purpose of augmenting one's cognitive functions (e.g., concentration, memory, or vigilance) without medical necessity. We use data from a large representative survey of German employees ($N = 6454$, response rate $= 29.8\%$). The Five Factor Model (FFM) of Personality was measured with a short version of the Big Five Personality Traits Inventory (BFI-S), which includes: openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. Together with this, demographic variables such as gender, age, education, and income were used as potential confounders in multiple logistic regression models. Our results show a 2.96% lifetime prevalence of CE-drug use and a 10.45% willingness to (re)use such drugs in the future. We found that less conscientious and more neurotic respondents have a higher probability of prior CE-drug use and a greater willingness to use CE drugs in the future. No significant effects were found for openness, extraversion, or agreeableness. Prior CE-drug use was strongly associated with a greater willingness to take such drugs in the future. This study shows that specific personality traits are not only associated with prior enhancement behavior, but also affect the willingness to (re)use such drugs. It helps increase understanding of the risk factors of CE-drug use, which is a health-related behavior that can entail severe side-effects for consumers. The knowledge gathered can thus help improve interventions aimed at minimizing health problems.

Keywords: pharmaceutical cognitive enhancement, non-medical use of prescription drugs, substance abuse, drug misuse, five-factor model, personality traits

INTRODUCTION

Personality traits, which can be described as differences between individuals regarding their behavior, thoughts, and feelings, can be seen as relatively stable in different situations and over time (Caspi, 1998; McCrae and Costa, 2008; Specht et al., 2014). These traits are important predictors of numerous personal, interpersonal, and social/institutional outcomes (Booth-Kewley and Vickers, 1994; Soldz and Vaillant, 1999). Among these are, for instance, happiness, physical and psychological health, longevity, criminal activity, and occupational choices (Booth-Kewley and Vickers, 1994; Ozer and Benet-Martinez, 2006; John et al., 2008). Personality traits (e.g., sensation seeking, neuroticism, impulsivity, anxiety) also seem to be variously associated with the use of different classes of substances and consumption intentions and therefore with risky health behavior that can have deleterious health consequences later in life (e.g., Herman-Stahl et al., 2006; Terracciano et al., 2008; Weyandt et al., 2009; Atherton et al., 2014; N'Goran et al., 2014; Maier et al., 2015).

In this study, we focus on the relationship between personality traits and the non-medical use of prescription drugs (e.g., methylphenidate, modafinil, donepezil) with the subjective aim of augmenting one's cognition (Glannon, 2008; Repantis et al., 2010; Smith and Farah, 2011). These drugs are usually prescribed to treat medical conditions, e.g., attention deficit disorder, narcolepsy, dementia, or Alzheimer's disease. This kind of cognitive enhancement (CE) can be defined as the intended or expected improvement of cognitive functions in healthy individuals in order to augment concentration, vigilance, memory, wakefulness, etc. (e.g., Bostrom and Sandberg, 2009; Repantis et al., 2010; Sattler and Wiegel, 2013)[1]. Given that clinical studies show that the effects of CE with current drugs are limited and sometimes even detrimental (Glannon, 2008; Repantis et al., 2010; Smith and Farah, 2011; Ragan et al., 2013), expectations regarding effectiveness seem often to be exaggerated (Repantis et al., 2010) while at the same time there are also potential risks in terms of side-effects and long-term health consequences (Sussman et al., 2006; Maher, 2008; Winder-Rhodes et al., 2010; Ragan et al., 2013). Beside these risks, the ethical debate about CE-drug use discusses several other potential negative consequences such as whether it undermines authenticity, amounts to cheating/is unfair, increases social inequality, results in direct or indirect coercion to also use such drugs, can burden the health care system, and can result in the involvement of the criminal justice system (Glannon, 2008; Greely et al., 2008; Bostrom and Sandberg, 2009; McLarnon et al., 2012; Dubljević et al., 2014; Sattler, in press).

Despite the possible detrimental effects and (long term) side effects of CE (Sussman et al., 2006; Glannon, 2008; Maher, 2008; Repantis et al., 2010; Winder-Rhodes et al., 2010; Smith and Farah, 2011; Ragan et al., 2013), healthy individuals take such medication for enhancement purposes. In addition to several studies questioning students about their CE use (Middendorff et al., 2012; Maier et al., 2013; Sattler and Wiegel, 2013; Wolff and Brand, 2013; Singh et al., 2014), only a few have surveyed the general population including the working population or parts of it. An informal survey among 1400 readers of the magazine *Nature* reported that 20% have already used such drugs for non-medical reasons to improve concentration, focus, or memory; these include methylphenidate (like Ritalin), modafinil (like Provigil), beta blockers (like propranolol), and/or others (Maher, 2008). The reported 12-month prevalence in a representative German study was 1.5% for drugs used to increase cognition and/or mood including prescription drugs (e.g., drugs counteracting depression such as fluoxetin and/or beta blockers) and illicit drugs (i.e., chemically synthesized stimulants such as amphetamines; Hoebel et al., 2011). A German health insurance company's survey of employees covered under its plans found that 4.7% used such drugs (i.e., stimulants such as methylphenidate, antidementives such as donepezil, and/or antidepressants such as fluoxetin) during their lifetime to enhance cognition and/or mood (DAK Gesundheitsreport, 2009) in a follow-up study prevalence increased to 6.7%, whereby 3.3% used drugs for CE (Marschall et al., 2015). Among German university teachers fewer than 1% reported prior non-medical use of prescription drugs to enhance cognitive performance (without specifying drugs or drug classes); however, more than 10% were willing to use such drugs in the future (Wiegel et al., 2015). This elevated willingness could turn into behavior under certain conditions, e.g., improved benefit-risk ratio or easier access (Singh et al., 2014; Wiegel et al., 2015), which would contribute to the predicted trend of increased CE-drug use.

Existing prevalence estimates are very heterogeneous, however. This is mainly due to inconsistent methods and measures across studies (Smith and Farah, 2011; Ragan et al., 2013; Ford and Ong, 2014; Maier et al., 2015; Sattler, in press). Most studies are not based on probability samples, but instead use small-scale samples, special populations, or combine prescription and illicit drugs or mood and CE into a single category. Thus, to get better estimates of the prevalence of CE-drug use, large-scale population-based probability samples have been strongly recommended (Hoebel et al., 2011; Mache et al., 2012; Sattler et al., 2013a; Fitz et al., 2014; Sattler, in press). Given the potential negative consequences of CE-drug use mentioned above, more empirical data about prevalence are needed on a regular basis for decision-making about the regulation of these drugs (Ragan et al., 2013; Maier and Schaub, 2015) to be better informed and also because of the assumption that the spread of CE drugs on the world market and on the Internet can scarcely be stopped (Sahakian and Morein-Zamir, 2007). More importantly, however, it is necessary to develop a better understanding of the antecedents to CE as a risky health-related behavior in order to inform prevention policies and to develop interventions for reducing its potential negative consequences (Booth-Kewley and Vickers, 1994; Terracciano et al., 2008).

While we can observe an increase in the number of studies that explore social, personal, and the characteristics of the

[1]In our study, we focus on prescription drugs that seem to dominate the current debate (e.g., Farah et al., 2004; Glannon, 2008; Greely et al., 2008; Racine and Forlini, 2010; Smith and Farah, 2011; Ragan et al., 2013; Schelle et al., 2014; Sattler, in press). Among these are drugs such as prescription stimulants (e.g., methylphenidate), antidementives (e.g., donepezil), and antidepressants (e.g., fluoxetine). The term "cognitive enhancement" generally encompasses the use of various potential enhancement means such as illegal drugs (e.g., cocaine), over-the-counter drugs (e.g., guarana), drugs naturally synthecized in the body (e.g., insulin), but also non-substance-based means such as mental training, sleep, brain stimulation (e.g.,Bostrom and Sandberg, 2009; Dresler et al., 2013).

substances as correlates of CE-drug use and willingness to use CE (Sattler and Wiegel, 2013; Wolff and Brand, 2013; Sattler et al., 2013a,b; Dubljević et al., 2014; Ford and Ong, 2014; Singh et al., 2014; Wolff et al., 2014; Maier et al., 2015; Wiegel et al., 2015), we still know very little about the role of psychological variables in relation to CE, in particular how personality characteristics affect CE-drug use. Accordingly, researchers have called for more studies on the effects of psychological variables (Quednow, 2010; Schelle et al., 2014; Wolff et al., 2014; Ponnet et al., 2015). Previous studies, for example, found that high achievement motivation (Franke et al., 2012), the inclination to procrastinate (Sattler et al., 2014; Ponnet et al., 2015), risk attitudes (Sattler and Wiegel, 2013; Sattler et al., 2014), stress (Wolff and Brand, 2013; Wiegel et al., 2015), high pressure to perform (Franke et al., 2013), cognitive test anxiety (Sattler and Wiegel, 2013; Sattler et al., 2014), trait impulsivity (Maier et al., 2015), Machiavellianism (Maier et al., 2015), novelty seeking (Maier et al., 2015), lower cognitive empathy (Maier et al., 2015), and burnout (Wolff et al., 2014) were positively associated with CE-drug use or willingness to use. Our study aims at increasing our knowledge about the antecedents of CE-drug use by further investigating the relationship between personality characteristics and CE. Since it is advisable to employ multidimensional systems of personality with a well-validated factor structure (Sher et al., 2000), we use the Five-Factor Model (FFM) of personality, which is a widely used and dominant paradigm in personality psychology (Costa and McCrae, 1995; Ozer and Benet-Martinez, 2006; Terracciano et al., 2008). It covers the five major traits: openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism (Costa and McCrae, 1995; Terracciano et al., 2008).

To our knowledge, this is the first study using a representative large-scale sample of German employees to investigate how personality traits are associated with CE. The only existing study that has examined the Big Five personality traits and a broad retrospective measure of CE (by combining certain prescription, non-prescription, and illegal drugs) with bivariate analyses is based on a student sample; the results are described below (Middendorff et al., 2012). Given this lack of research, our study can be informed by studies on the Big Five personality traits and other forms of substance use and misuse such as tobacco, alcohol, prescription stimulants, marihuana, etc.

Openness to experience can be described as a person's appreciation of new experiences and stimulation due to being imaginative, creative, unconventional, and emotionally as well as aesthetically sensitive (Caspi et al., 2005; John et al., 2008; Terracciano et al., 2008). It has been assumed that this willingness to engage in new experiences is a risk factor for the non-medical use of prescription drugs (Benotsch et al., 2013) and/or for detrimental substance use (Turiano et al., 2012). Specifically for CE, a greater openness to experiences has been presumed to promote CE-drug use due to higher eagerness to experiment (Middendorff et al., 2012). Several studies corroborate this assumption by showing that, for example, higher openness was positively associated with marijuana use (Terracciano et al., 2008) or illegal drug use in general (Turiano et al., 2012), opioid dependency (Kornør and Nordvik, 2007), cigarette smoking (Turiano et al., 2012), problem drinking (Turiano et al., 2012), a broader measure of substance-related risk-taking (defined as drinking, driving after drinking, smoking tobacco; Booth-Kewley and Vickers, 1994), substance-use disorder (Trull and Sher, 1994), and the non-medical use of prescription drugs (Benotsch et al., 2013). However, the only existing study of a set of different CE drugs found no effect (Middendorff et al., 2012).

Conscientiousness refers to an ability to control behavioral and cognitive impulses "that facilitates task- and goal-directed behavior, such as thinking before acting, delaying gratification, following norms and rules, and planning, organizing, and prioritizing tasks" (John et al., 2008, p. 138; cf. Caspi et al., 2005; Terracciano et al., 2008). It is seen as a protective factor against the non-medical use of prescription drugs (Benotsch et al., 2013) and the latter's specific form of CE-drug use (Middendorff et al., 2012), but also more generally against the detrimental use of other substances (Turiano et al., 2012). High levels of conscientiousness are assumed to play an important self-regulatory role and are associated with discipline and persistence and thus with disregarding the immediate gratification of health-damaging behaviors in order to obtain future, long-term outcomes (such as long-term health) "instead of" positive future, long-term health (Middendorff et al., 2012; Turiano et al., 2012; Benotsch et al., 2013). One argument is that since a reduced ability to engage in systematic and organized behavior has detrimental effects on learning, CE-drug use might be a means to compensate for these effects (Middendorff et al., 2012). Prior research has shown that procrastination, which can be seen as an example of this reduced ability, predicts a willingness to use CE drugs (Sattler et al., 2014). The only study on CE-drug use and conscientiousness thus far has also described a negative association between the two, namely that more conscientious students less were less likely to report using several drugs for purposes of CE (Middendorff et al., 2012). Furthermore, for a majority of respondents, CE-drug use violates social norms (e.g., fairness; Sattler et al., 2013b; Dubljević et al., 2014; Schelle et al., 2014; Wiegel et al., 2015; Sattler, in press) and since conscientious individuals tend to follow norms and rules, they might be less likely to use such drugs. Research on other types of substance use also found that increased conscientiousness is associated with a lower incidence of cigarette smoking (Terracciano et al., 2008; Turiano et al., 2012), of non-medical use of prescription drugs (Turiano et al., 2012; Benotsch et al., 2013), of use of illegal drugs such as marijuana, cocaine, and hallucinogens/lysergic acid diethylamide (LSD) (Terracciano et al., 2008; Turiano et al., 2012), of alcohol consumption (Malouff et al., 2007; Turiano et al., 2012), of substance use disorders (Trull and Sher, 1994), and specifically of opioid dependency (Kornør and Nordvik, 2007) as well as lower more general measures of the use of substances including cigarettes, alcohol, and recreational drugs (Atherton et al., 2014; cf., Lackner et al., 2013).

Extraversion reflects an energetic approach toward the world and can be understood as a person's tendency to be outgoing, expressive, active, energetic, assertive, cheerful, sociable, and in search of stimulation (Caspi et al., 2005; John et al., 2008; Terracciano et al., 2008). Some researchers have assumed neither an association between extraversion and CE-drug use specifically (Middendorff et al., 2012), nor with substance use in general (Turiano et al., 2012). However, several studies disprove

this assumption. For example, it has been found that higher extraversion correlates with increased alcohol consumption (Turiano et al., 2012), more tolerant attitudes toward substance use (Francis, 1996), and more frequent use of substances including cigarettes, alcohol, and recreational drugs (Atherton et al., 2014). Yet, the association between extraversion and substance use may depend on the specific substance in question. Studies found that extraversion was higher in smokers as well as marijuana and cocaine/heroin users (Terracciano et al., 2008) but lower for opioid dependents (Kornør and Nordvik, 2007). A broad CE-measure, however, was uncorrelated with extraversion.

Agreeableness can be defined as a person's pro-social and communal orientation and includes a person's tendency to be altruistic, trustworthy, cooperative, considerate, empathic, polite, and modest (Caspi et al., 2005; John et al., 2008; Terracciano et al., 2008). While it has been assumed that agreeableness associates negatively with substance use (Booth-Kewley and Vickers, 1994; Turiano et al., 2012), for CE-drug use specifically it has been predicted that there would be no effect (Middendorff et al., 2012). This latter assumption has been supported by one study (Middendorff et al., 2012). For other substances, agreeableness seems to have a protecting effect, since more agreeable persons report lower marijuana use (Terracciano et al., 2008), alcohol consumption (Malouff et al., 2007; Turiano et al., 2012), non-medical use of prescription drugs (Benotsch et al., 2013), polydrug abuse (Lackner et al., 2013), and alcohol dependency (Kornør and Nordvik, 2007).

Neuroticism includes feelings such as anxiety, nervousness, sadness, and depression and thus reflects a tendency to experience negative emotions (Caspi et al., 2005; John et al., 2008; Terracciano et al., 2008). Neuroticism is seen as a risk factor for CE-drug use (Middendorff et al., 2012) and more generally for the non-medical use of prescription drugs as well (Benotsch et al., 2013), but also for the use of other substances (Turiano et al., 2012). According to the self-medication hypothesis (Khantzian, 1997; West, 2005), individuals use drugs and may become dependent on them because they are vulnerable to stress, emotionally unstable, and thus may use CE to cope with emotional distress (Kornør and Nordvik, 2007; Benotsch et al., 2013). Contrary to these assumptions, neurotic individuals might also be more anxious about the potential side effects of CE-drug use, which might inhibit their use. However, several studies have corroborated that more neurotic individuals report higher use of a variety of substances, e.g., a broad CE-measure (Middendorff et al., 2012), alcohol consumption (Malouff et al., 2007; Turiano et al., 2012), cigarette smoking (Terracciano et al., 2008; Turiano et al., 2012), illegal drug use (Turiano et al., 2012) including cocaine and heroin (Benotsch et al., 2013), and prescription drug use especially anxiolytics and sedatives (Turiano et al., 2012; Benotsch et al., 2013); they are also more likely to report polydrug addiction (Lackner et al., 2013) and drug use disorder (Sher et al., 2000).

Due to scarce data on CE-drug use and the FFM and given the often inconsistent correlations between Big Five dimensions and many kinds of substance use and misuse from heterogeneous studies, there is a clear need for more research in this field (e.g., Booth-Kewley and Vickers, 1994; Francis, 1996; Malouff et al., 2007; Terracciano et al., 2008; Turiano et al., 2012; Benotsch et al., 2013; Lackner et al., 2013; Atherton et al., 2014).

By using data from a representative, large-scale random sample of German employees, this study aims at expanding our understanding of the prevalence of prior non-medical use of prescription drugs (a retrospective measure) and the willingness to use such drugs in the future (a prospective measure) with the subjective purpose of augmenting one's cognitive performance (by improving functions such as concentration, memory, or vigilance) as well as the association between the prevalence and willingness and the FFM traits. On a more general level, the study also adds to our understanding of the effect of personality traits on substance use: although mainly illicit drugs as well as substances such as alcohol and nicotine have been investigated in this regard, the non-medical use of prescription drugs has less frequently been the subject of research (Benotsch et al., 2013; N'Goran et al., 2014). Moreover, several studies on substance use and personality traits have investigated only one or a subset of traits of the FFM, while the present study investigates all five domains (Booth-Kewley and Vickers, 1994; Turiano et al., 2012; N'Goran et al., 2014).

METHODS

Research Design and Data

Data

The data for this study are based on the first wave of the B3 Linked Employer-Employee Panel Survey (LEEP-B3) (Diewald et al., 2014). For the purpose at hand, we use the employee-survey of the LEEP-B3 data, which were collected as computer-assisted telephone interviews (CATI) in 2012–13 in Germany. Prior to the interviews selected participants were informed by a cover letter about the subject of the study, the voluntariness of their participation, their anonymity, and the confidentiality of all their answers. These issues were explained again during the first telephone contact. The underlying population comprises all employees in Germany who are subject to social security contributions, which applies to the majority of German employees—excluding only self-employed, marginally employed, apprentices, and civil servants. The net sample comprised 21,678 eligible respondents. The response rate was 29.77%, which leads to a total sample of 6454 (Diewald et al., 2014). Multivariate selectivity analyses comparing the sample to the underlying population using German registry data indicate that the LEEP-B3 data represent the underlying population rather well (Diewald et al., 2014). There is some limited selectivity, namely people who are German nationals and work in the "information and communication" sector participated in greater numbers, whereas people with lower levels of education and those working in very large organizations were less likely to participate.

Ethics Statement

In Germany, ethics approval for social science research is not required if research objectives do not investigate issues regulated by law (e.g., the German Medicine Act [Arzneimittelgesetz, AMG], the Medical Devices Act [Medizinproduktegesetz, MGP],

the Stem Cell Research Act [Stammzellenforschungsgesetz, StFG], or the Medical Association's Professional Code of Conduct [Berufsordnung der Ärzte]). Since our study had no such objectives, approval was not required. Furthermore, paragraph 28 of the Data Protection Act of North Rhine Westphalia (Datenschutzgesetz Nordrhein-Westfalen, DSG NRW) explains that personal data have to be processed anonymously and that participants' consent is required only when the data are not used anonymously. Since data were collected in cooperation with the federal Institute for Employment Research (Institut für Arbeitsmarkt und Berufsforschung, IAB; Diewald et al., 2014), the study and all procedures were approved by the data security officer of the federal IAB and the Federal Ministry of Labor and Social Affairs (Bundesministerium für Arbeit und Soziales, BAMS). Prior to the interviews the selected participants were informed by a cover letter about the subject of the study. This letter explicitly informed the potential participants of the voluntariness of their participation, their anonymity, and the confidentiality of all their answers. During the first telephone contact, potential participants were again explicitly informed that their participation was voluntary, that all answers would be treated confidentially, and that the data would be anonymized. Thus, the act of participating in the study after receiving all relevant confidentiality information was taken to imply understanding and agreement.

Measures

Prior CE-Drug Use

We measured prior CE-drug use by asking: "Some people support their cognitive abilities with the help of prescription drugs, though there is no medical need (e.g., for increasing concentration, memory, or vigilance). Have you ever done that?" We provided the following response categories: "no, never" (0); "yes, within the last 30 days" (1); "yes, between the last 30 days and 6 months" (2); "yes, between the last 6 months and 1 year" (3); "yes, more than 1 year ago" (4) (cf. Sattler and Wiegel, 2013; Wiegel et al., 2015). Due to the low prevalence (see **Table 1**), a dichotomous variable was computed for our multivariate analysis, indicating no use (0) and prior use (1) (cf. Wiegel et al., 2015).

Willingness to Use CE Drugs

Given that CE-drug use can be described as a relatively new and potentially increasing phenomenon (e.g., Farah et al., 2004; Castaldi et al., 2012), we also assessed the respondents' willingness to use CE drugs, since this can be seen as one method for determining whether the postulated trend exists (Wiegel et al., 2015). Willingness measures are often used in research on the use of (licit and illicit) substances such as tobacco, alcohol, amphetamines, and marijuana, since they are used as proximal antecedents of future behavior (Gibbons et al., 1998a,b; Gerrard et al., 2006). However, an imperfect correlation between this measure and behavior may exist, since behavioral restrictions can change over time (cf. Grasmick and Bursik, 1990). But such measures are assumed to be less sensitive than behavioral measures and thus should result in fewer item-non responses or biased responses (e.g., Gibbons et al., 1998b). The CE-willingness measure was similar to the prior CE-drug use measure. Respondents were asked whether they could imagine using (or reusing) such prescription drugs for CE in the future (cf. Ponnet et al., 2015; Wiegel et al., 2015). Dichotomous response categories were "No, I would not do that under any circumstances" (0) and "Yes, I would do that under certain circumstances" (1) (cf. ZUMA, 1990).

Personality Traits

We used a short version of the Big Five Personality Traits Inventory (BFI-S) (Gerlitz and Schupp, 2005; Dehne and Schupp, 2007; Hahn et al., 2012) to assess the components of the FFM of personality (e.g., Costa and McCrae, 1995). Each of the five factors (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism) were measured by three items on five-point scales ranging from "I agree entirely" (1) to "I do not agree at all" (5). The items have been reverse-coded so that higher values indicate stronger agreement with the underlying factor (see Table S1). With regard to reliability, the BFI-S is a reasonable instrument for measuring the FFM in large, multi-purpose surveys (Lang et al., 2011). Similar to prior research (Dehne and Schupp, 2007), reliability analysis of the scales showed moderate internal consistencies: openness to experiences (artistic experiences, ideas, active imagination, $\alpha = 0.53$), extraversion (talkative, sociable, reserved, $\alpha = 0.66$), conscientiousness (efficient, thorough job, lazy, $\alpha = 0.55$), agreeableness (forgiving, kind, rude, $\alpha = 0.45$), and neuroticism (worried, nervous, relaxed, $\alpha = 0.54$). However, since each item is supposed to measure a distinct facet within each dimension, the relatively low alpha values can be seen as an indication of the distinctness of the underlying facets (Rammstedt, 2010). We used explanatory factor analysis with varimax rotation to extract the five factors from the BFI-S (see Table S1). All items loaded substantially on the respective factor (openness with a mean factor loading of 0.68; extraversion with a mean factor loading of 0.76; conscientiousness with a mean factor loading of 0.69; agreeableness with a mean factor loading of 0.66; and neuroticism with a mean factor loading of 0.71) and showed low secondary loadings on other factors (mean secondary loading = 0.07).

Demographic Variables

Women were coded "0" and men "1" (see **Table 1** for this and other descriptive statistics). We also assessed gender (female = 0 and male = 1), age, education in years (each educational degree is assigned the average duration it takes to obtain), and personal gross monthly earnings in Euro.

Missing Values

The proportion of missing values is generally low (see **Table 1**). The highest proportion of missings can be found with earnings (4.93%, $n = 318$). Missing values were imputed using multivariate imputation by chained equations (MICE) (Azur et al., 2011; White et al., 2011) with 20 data sets. The following multivariate analyses are based on the imputed data sets, but all analyses have also been carried out using the unimputed data set (see Tables S2, S3).

TABLE 1 | Descriptive statistics with non-imputed data.

	Mean	Standard deviation	Min	Max	Observations	Observations with missing values (in %)
COGNITIVE ENHANCEMENT						
Prior CE-drug use[a]	0.03	–	0.00	1.00	6444	10 (0.15)
Willingness to use CE drugs	0.10	–	0.00	1.00	6332	122 (1.89)
BIG FIVE PERSONALITY TRAITS INVENTORY						
Openness to experiences	0.00	1.00	−3.76	2.92	6407	47 (0.73)
Conscientiousness	0.00	1.00	−5.89	2.82	6407	47 (0.73)
Extraversion	0.00	1.00	−3.46	2.49	6407	47 (0.73)
Agreeableness	0.00	1.00	−4.84	2.60	6407	47 (0.73)
Neuroticism	0.00	1.00	−3.02	3.46	6407	47 (0.73)
SOCIO-DEMOGRAPHIC CONTROLS						
Male	0.53	–	0.00	1.00	6454	0 (0.00)
Age in years	40.63	8.64	19.00	52.00	6454	0 (0.00)
Education in years	14.04	2.83	7.00	18.00	6408	46 (0.71)
Gross monthly earnings in Euro	3766.70	3650.65	13.27	125,000.00	6136	318 (4.93)

Source: LEEP-B3, own computations.

[a]This category includes 50 (0.78%) respondents indicating CE-drug use within the last 30 days, 24 (0.37%) respondents indicating such usage between the last 30 days and 6 months, 27 (0.42%) respondents indicating such usage between the last 6 months and 1 year and 90 respondents (1.40%) indicating that such usage was more than 1 year ago.

Statistical Analysis

We used logistic regression models to test how the dependent variables covary with the independent variables. We report odds ratios (OR). ORs greater than 1 indicate positives effects of the independent variables on the respective dependent variable, while ORs lower than 1 indicate a negative effect, and ORs equal to 1 indicate no effect. The reported *p*-values are based on robust standard errors.

RESULTS

Prior CE-Drug Use

Our descriptive results (based on non-imputed data) show that approximately 97.04% ($n = 6253$) of the respondents report that they have never used prescription medication non-medically to support their cognitive abilities (see **Table 1**), while 2.96% ($n = 191$) reported such CE-drug use during their lifetime (see **Table 1**). In particular, 0.78% ($n = 50$) reported having used such drugs within the last 30 days, 0.37% ($n = 24$) between the last 30 days and 6 months, 0.42% ($n = 27$) between the last 6 months and 1 year, and 1.40% ($n = 90$) reported having used such drugs over a year ago. Our multivariate analysis (based on imputed data) focuses on the lifetime prevalence of CE-drug use only (see Methods section). Results show an OR of 0.774 ($p < 0.001$) in Model 1 in **Table 2**, which indicates a significant negative association between conscientiousness and prior CE-drug use. Thus, more conscientious respondents had a lower probability of prior CE-drug use. Moreover, we found a positive association between neuroticism and CE-drug use ($p < 0.001$). No significant associations were found for openness to experiences ($p = 0.101$), extraversion ($p = 0.416$), or agreeableness ($p = 0.376$). Prior use of CE drugs did not significantly vary with the socio-demographic controls gender ($p = 0.865$), age ($p = 0.811$), and earnings ($p = 0.404$)[2]. Education, however, was found to have a negative association with prior CE-drug use ($p = 0.049$).

Willingness to Use CE Drugs

10.45% ($n = 662$, based on non-imputed data) of the respondents reported being willing to consume CE drugs in the future, while the remaining 89.55% ($n = 5.670$) indicated that they would never use such drugs (see **Table 1**). Multivariate analysis (based on imputed data) shows that the willingness to use CE drugs decreased if respondents showed stronger tendencies toward conscientiousness ($p < 0.001$) and it increased if respondents reported higher levels of neuroticism ($p < 0.001$) (see Model 2 in **Table 2**). Again, the effects for the domains openness to experience ($p = 0.687$), extraversion ($p = 0.128$), and agreeableness ($p = 0.080$) reached no conventional levels of significance. Males were less willing to use CE drugs in the future compared to females ($p = 0.012$). Age ($p = 0.320$), education ($p = 0.414$), and earnings ($p = 0.848$) had no significant effects on the willingness to use CE drugs[3]. Respondents reporting the use of CE drugs in the past were much more willing to consume such drugs in the future compared to those who had never used such drugs ($p < 0.001$; **Table 2**, Model 3). Finally, we tested whether the effects of the five personality domains and the socio-demographic variables were conditional on prior use by adding interaction terms of these variables with prior use (see Table S3). Results show that no differential effects exist, i.e., the effects of the five personality domains and the socio-demographics on

[2]In line with a developmental framework (e.g.,McLarnon et al., 2012), individuals in different stages of life might have different demands or propensities to use CE drugs (e.g., due to different peer exposure, risk preferences, or stressful periods). We therefore additionally tested quadratic and cubic functions of the age effect. Because no such effects were found, we do not show the results.

[3]Again, quadratic and cubic functions of the age effect were not significant.

TABLE 2 | Logistic regression models to assess associations of the BFI-S and socio-demographic controls with prior CE-drug use (Model 1) and the willingness to use CE drugs (Model 2 and 3) with imputed data (Number of imputations = 20, Number of observations = 6454).

	Model 1 Prior CE-drug use		Model 2 Willingness to use CE drugs		Model 3 Willingness to use CE drugs	
	OR	95% CI	OR	95% CI	OR	95% CI
Openness to experience	1.129	[0.977, 1.305]	1.018	[0.935, 1.107]	0.999	[0.914, 1.092]
Conscientiousness	0.774***	[0.674, 0.888]	0.810***	[0.748, 0.876]	0.831***	[0.766, 0.903]
Extraversion	1.061	[0.919, 1.225]	1.067	[0.981, 1.159]	1.062	[0.975, 1.158]
Agreeableness	0.941	[0.822, 1.077]	0.931	[0.859, 1.009]	0.934	[0.858, 1.017]
Neuroticism	1.352***	[1.154, 1.584]	1.303***	[1.197, 1.418]	1.264***	[1.158, 1.379]
Male	0.865	[0.628, 1.192]	0.798*	[0.669, 0.951]	0.802*	[0.667, 0.964]
Age in years	0.998	[0.981, 1.015]	1.005	[0.995, 1.015]	1.006	[0.996, 1.016]
Education in years	0.944*	[0.891, 1.000]	0.988	[0.958, 1.018]	0.997	[0.966, 1.029]
Gross monthly earnings in Euro	1.000	[1.000, 1.000]	1.000	[1.000, 1.000]	1.000	[1.000, 1.000]
Prior CE-drug use					17.320***	[12.608, 23.792]
Constant	0.080***	[0.025, 0.256]	0.120***	[0.066, 0.220]	0.083***	[0.045, 0.156]
Log pseudolikelihood	−840.449		−2114.087		−1955.289	
Pseudo R^2	0.026		0.021		0.094	

Source: LEEP-B3, own computations.

OR = Odds Ratios. CI = 95% confidence intervals in parentheses (based on robust standard errors). Log pseudolikelihood and Pseudo R^2 are averaged across imputed datasets.

**p < 0.05, **p < 0.01, ***p < 0.001.*

the willingness to use CE drugs do not differ between users and non-users.

To facilitate the interpretation, the main results concerning the association between prior CE-drug use and the two personality traits of conscientiousness and neuroticism as well as the association between willingness to use CE drugs and these two traits are displayed in **Figure 1**. It shows predicted probabilities for both CE-measures using average marginal effects based on the multivariate models in **Table 2**. The predicted probabilities show that the effects associated with conscientiousness and neuroticism are rather large. The predicted difference between respondents with a low [defined by the mean (M) minus one standard deviation (SD)] and a high level of conscientiousness (M + 1 SD) is 39 percentage points (3.71 vs. 2.26%) in prior use and 31 percentage points regarding willingness to use (12.38 vs. 8.51%) (**Figures 1A,C**). As regards neuroticism, the predicted difference between respondents with a high level (M + 1 SD) and respondents with a low level (M – 1 SD) of this personality trait is 44 percentage points in prior use (3.76 vs. 2.10%) and 38 percentage points in willingness to use CE drugs (12.78 vs. 7.98%) (**Figures 1B,D**).

DISCUSSION

Summary and Interpretation of the Results

Prevalence of CE-Drug Use and the Willingness to Take CE Drugs

While there is a fierce debate about whether CE-drug use is already a widespread phenomenon or whether it will be widespread in the future (Sahakian and Morein-Zamir, 2007; Greely et al., 2008; Ragan et al., 2013; Sattler et al., 2013a), limited research has been based on prevalence estimates derived from large-scale random samples beyond student populations (Hoebel et al., 2011; Mache et al., 2012; Sattler et al., 2013a; Fitz et al., 2014; Sattler, in press). We add to this research with data from more than **six** thousand employees in Germany randomly selected for this study (Diewald et al., 2014). We found a lifetime prevalence of nearly 3% for use of prescription drugs for supporting cognitive performance. This figure falls in the range of prevalence estimates of comparable prior studies (DAK Gesundheitsreport, 2009; Hoebel et al., 2011; Marschall et al., 2015) and shows that CE-drug use is already a fact, even if not a general practice, which opposes the current media hype about CE. Still, it has been estimated that more than half a million individuals in Germany have experience with CE-drug use (Kowalski, 2013); it can be presumed that a large number of these continue using (Sattler and Wiegel, 2013; Sattler et al., 2014; Wiegel et al., 2015), risking potential detrimental health effects often with no real effects or even detrimental effects. But the willingness to use such drugs in the future was more than three times greater than lifetime prevalence. More than every 10th respondent indicated such a willingness. A similar difference between prior and potential future use has been found in a study of university teachers (Wiegel et al., 2015). Of course expressed willingness does not necessarily translates into actual behavior, for example due to changes in behavioral restrictions (cf. Grasmick and Bursik, 1990). However, discrepancies between willingness and use of CE drugs may also be explained by other factors. For example, potential users may not yet have experienced a pressing need to take such drugs, but would do so if the need were to occur, or they might not have had the opportunity (e.g., due to lack of access) to convert their interest into use (Singh et al., 2014; Wiegel et al., 2015). But drugs may become more available via the Internet and on the black market (Sahakian and Morein-Zamir, 2007). Potential users may also

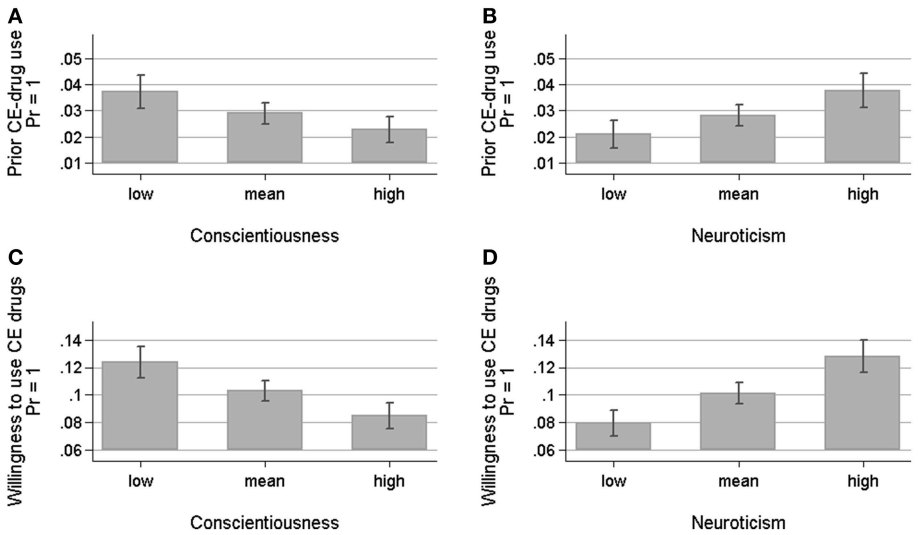

FIGURE 1 | Predicted probabilities of prior use and willingness (both y-axis) estimated using average marginal effects based on multivariate logistic regression models—error bars represent the 95% confidence interval. (A) shows that the predicted probability of prior CE-drug use is higher in case of lower conscientiousness [defined by the mean value (M) − 1 standard deviation (SD)] compared to the M and to higher conscientiousness (M + 1 SD), while the probability **(B)** is lower for lower levels of neuroticism (M – 1 SD) compared to the M and to higher neuroticism (M + 1 SD) (based on Model 1, **Table 2**). **(C,D)** show similar effects for the willingness to use CE drugs (based on Model 2, **Table 2**).

want to wait until more effective and safer medication is available (DAK Gesundheitsreport, 2009; Franke et al., 2012; Wiegel et al., 2015).

Associations between Big Five Personality Traits and Prior CE-Drug Use and the Willingness to Engage in CE-Drug Use

Only relatively few studies (e.g.,Franke et al., 2012, 2013; Sattler and Wiegel, 2013; Wolff and Brand, 2013; Sattler et al., 2014; Wiegel et al., 2015; Maier et al., 2015) have responded to one of the first appeals for investigating how personality relates to CE-drug use (Quednow, 2010); in these the Big Five traits—which represent an important set of traits—have generally been ignored, with the exception of one study among students (Middendorff et al., 2012). By investigating the association between Big Five traits and prior CE-drug use as well as the willingness to use CE drugs in the future, we hope to add to our understanding of how a set of five major personality traits relates to such behavior. This also contributes to the often inconsistent findings between various kinds of substance use and misuse (including tobacco, alcohol, prescription stimulants, marihuana, etc.) and the FFM (e.g., Booth-Kewley and Vickers, 1994; Francis, 1996; Malouff et al., 2007; Terracciano et al., 2008; Turiano et al., 2012; Benotsch et al., 2013; Lackner et al., 2013; Atherton et al., 2014).

Similarly to a study of students using a broad retrospective measure of CE that combines certain prescription, non-prescription, and illegal drugs (Middendorff et al., 2012), we found that openness to experience was unrelated to both prior CE-drug use and the willingness measure. This, however, contradicts the assumption that the tendency to engage in new experiences and a greater eagerness to experiment produce a risk factor of higher involvement in substance use (Middendorff et al., 2012; Turiano et al., 2012; Benotsch et al., 2013). It also contradicts several findings regarding the use of multiple substances (e.g., illegal drug use, cigarette smoking, the non-medical use of prescription drugs), which found associations consistent with this assumption (e.g., Booth-Kewley and Vickers, 1994; Trull and Sher, 1994; Kornør and Nordvik, 2007; Terracciano et al., 2008; Turiano et al., 2012; Benotsch et al., 2013).

Respondents with higher levels of conscientiousness were less likely to report prior CE-drug use as well as a willingness to use CE drugs in the future. This is consistent with the supposition that conscientiousness serves as a protective factor against substance use (Middendorff et al., 2012; Turiano et al., 2012; Benotsch et al., 2013) and corroborates prior findings on a broad CE-drug measure (Middendorff et al., 2012) as well as many other substances such as alcohol consumption, cigarette smoking, prescription drug use, and illegal drug use (e.g., Trull and Sher, 1994; Kornør and Nordvik, 2007; Malouff et al., 2007; Terracciano et al., 2008; Turiano et al., 2012; Benotsch et al., 2013; Lackner et al., 2013; Atherton et al., 2014). This protective effect could be due to better self-regulation and persistence, which help to control impulses and delay the immediate gratifications of potentially health-damaging behaviors, while aiming for positive, long-term outcomes (such as long-term health) (Middendorff et al., 2012; Benotsch et al., 2013; Turiano et al., 2012). But also a greater ability to engage in systematic and organized behavior and consequently achieving better performance outcomes reduces the need to use CE drugs to compensate for the lack of such an ability (Middendorff et al., 2012). Furthermore, the increased tendency of conscientious individuals to follow norms might also decrease their likelihood to engage in behavior that many consider as

morally objectionable (Sattler et al., 2013b; Dubljević et al., 2014; Schelle et al., 2014; Wiegel et al., 2015; Sattler, in press).

Our results also show no significant covariation between extraversion and our two CE-measures. This finding corroborates researchers' assumption that no such association should exist (Middendorff et al., 2012; Turiano et al., 2012) as well as the results of one study that found no association between CE-drug use and extraversion (Middendorff et al., 2012); at the same time some studies found that higher levels of extraversion can be associated with increased consumption of several substances (e.g., Kornør and Nordvik, 2007; Terracciano et al., 2008; Turiano et al., 2012; Atherton et al., 2014).

Agreeableness was neither significantly associated with our retrospective nor with the prospective CE-measure and thereby supports prior research on agreeableness and CE as well as the assumption that no such effect exists (Middendorff et al., 2012). For the use of other substances a negative association has been predicted (Booth-Kewley and Vickers, 1994; Turiano et al., 2012) and found (e.g., Kornør and Nordvik, 2007; Malouff et al., 2007; Terracciano et al., 2008; Turiano et al., 2012; Benotsch et al., 2013; Lackner et al., 2013), showing that agreeableness seems to have a protective effect.

It has also been shown that increased neuroticism leads to higher probabilities of prior CE-drug use and willingness to use CE drugs. Our results thus support the assumption that neuroticism is a risk factor for several kinds of substance use (Middendorff et al., 2012; Turiano et al., 2012; Benotsch et al., 2013). They also corroborate prior findings on a broad CE-measure (Middendorff et al., 2012) and other substances including prescription drugs, alcohol, nicotine, and illegal drugs (Sher et al., 2000; Malouff et al., 2007; Terracciano et al., 2008; Turiano et al., 2012; Benotsch et al., 2013; Lackner et al., 2013). One reason for these findings could be that neurotic individuals are less emotionally stable and more vulnerable to stress and therefore use these substances to cope with emotional distress (Kornør and Nordvik, 2007; Benotsch et al., 2013).

Associations Between Demographic Controls and Prior CE-Drug Use and Willingness to Engage in CE-Drug Use

With regard to the demographic controls, we found almost no significant differences regarding prior and potential future CE-drug use. While prior studies have shown mixed gender effects—generally finding no effect or a higher prevalence for males, but also that the purpose of use or the types of drugs used differ between sexes (e.g., McCabe et al., 2005; Rabiner et al., 2009, 2010; Weyandt et al., 2009; Ford and Ong, 2014; Singh et al., 2014; Ponnet et al., 2015; Wiegel et al., 2015)—our study found that women showed a higher willingness to use CE drugs, which is consistent with another German large-scale study (Hoebel et al., 2011). It has been assumed that such effects could indicate structural discrimination against women, namely that women need to work harder than men to rise in the hierarchy and at the same time often have twice or three times the amount of chores (work, children, and household) (Wiegel et al., 2015). This might increase the incentive for women to use such drugs as leverage in the job and to deal with their larger workload. Prior findings about the age-effect were indecisive (e.g., Maher, 2008; Terracciano et al., 2008; Benotsch et al., 2013; Ragan et al., 2013; Sattler and Wiegel, 2013; Sattler et al., 2013a; Ford and Ong, 2014; Singh et al., 2014; Wiegel et al., 2015), however, we found no age effect for both outcome variables. More years of education, however, were associated with a lower reporting of prior CE-drug use, which contradicts, for example, the study of Hoebel et al. (2011), which found no significant differences. One explanation could be that increased education is associated with greater knowledge about the limited efficiency of CE drugs. Additionally, for those with lower education, CE could be one means of compensating for lowered chances in the labor market or of dealing with potentially burdensome demands from their jobs. These assumptions have to be verified by future research. Respondents with potentially more monthly financial resources reported no elevated prior CE-drug use or willingness to do so in the future. In keeping with prior findings (Sattler and Wiegel, 2013; Sattler et al., 2014; Wiegel et al., 2015) and reasoning consistent with the Theory of Planned Behavior (Beck and Ajzen, 1991; Ouellette and Wood, 1998), we found a strong positive effect of prior CE-drug use on the willingness to consume such drugs in the future, indicating that many users have not only experimented once with these drugs but intend to continue using them (cf. Müller and Schumann, 2011). Users may have already made up their minds about their preferences or may be influenced by other factors such as a lack of self-control, sticking with their decisions out of habit and without further deliberation; they may have had positive experiences; or, in order to reduce potential cognitive dissonance, they may justify prior and continued drug consumption by ignoring negative information about CE-drug use or perceiving supporting information on a selective basis (Beck and Ajzen, 1991; Ouellette and Wood, 1998; Caviola et al., 2014; Wiegel et al., 2015).

Limitations and Strengths of the Study and Directions for Future Research

The awareness of potential limitations is important when interpreting our results. We will describe these together with the strengths of our study as well as suggest directions for future research:

1. Our response rate of 29.77% can be compared to similar studies (Bender et al., 2009; Schmich, 2015). But a considerable amount of invitees did not participate in our survey, which can reduce the external validity of the results if this non-response is selective. However, a comparison between the target population (information derived from German registry data) and our sample shows a high correspondence between socio-demographic characteristics, indicating limited problems of selectivity (see Methods section) (Diewald et al., 2014). Since we used a large representative population-based sample, our results might be more generalizable than the numerous small scale and non-representative samples in the field of CE-research and of research on the association between BFI and the non-medical use prescription drugs.
2. Our sample covers only the employed German population subject to social insurance contributions, hence it does not

provide a full picture of the general population in Germany. However, our target population can be considered a large and important group in society. More research has been requested for our under-investigated target population (Greely et al., 2008; Ragan et al., 2013; Fitz et al., 2014; Schelle et al., 2014; Sattler, in press). This request is due to the repeated critique that most prior studies on factors influencing CE-drug use solely focused on students or other specific populations (Cutler, 2014; Ford and Ong, 2014; Wolff et al., 2014; Maier et al., 2015; Wiegel et al., 2015) and thus faced a limited generalizability.

3. We only investigated individuals from one country. CE-drug use as well as the association between CE and BFI might differ across countries, for example, due to varying regulations, social acceptance, advertisement, and the availability of CE drugs as well as (legal and illegal) alternative drugs that serve as substitutes (cf. Terracciano et al., 2008; Bell et al., 2013; N'Goran et al., 2014; Wiegel et al., 2015; Sattler, in press). Studies in other countries using a methodology similar to ours could provide insights about the cross-cultural generalizability of our results.
4. Several studies investigating the relationships between personality traits and (non-medical) drug (mis-)use investigate only a subset of Big Five traits (Terracciano et al., 2008). We assessed all five domains and thus can offer a more complete picture of these relationships. Since we could only employ a short scale of the Big Five Personality Traits Inventory (Gerlitz and Schupp, 2005; Dehne and Schupp, 2007; Hahn et al., 2012), only overall effects of the five higher level personality factors were explored (cf. Turiano et al., 2012). The BFI-S showed only moderate values concerning reliability, which has been documented in previous research (Dehne and Schupp, 2007). However, one would not expect high alpha values if each (single) item is supposed to capture a specific facet within a trait (Rammstedt, 2010). More importantly, however, the factor loadings were high and unambiguous, indicating that the BFI-S captures the underlying latent personality dimensions rather well. Still, future studies should investigate the full BFI or the NEO-PI-R (Berth and Goldschmidt, 2004; Ostendorf and Angleitner, 2004; Soto and John, 2009) to see if the results can be replicated with broader measures of personality and which lower level personality-facets of each trait are specifically relevant and predictive due to their higher specificity. It has been argued, however, that interpreting effects of domains is more basic and "combines information from several scales in meaningful ways and allows us to make more powerful inferences about personality traits and correlates that are not directly measured" (Costa and McCrae, 1995, p. 46). In addition to these instruments that target the Big Five traits, other personality trait inventories as well should be employed in future studies, such as the Minnesota Multiphasic Personality Inventory (MMPI) (e.g., Butcher, 2010), the 16PF Questionnaire (e.g., Cattell and Mead, 2008), or the Myers-Briggs Type Indicator (MBTI) (e.g., Myers et al., 1985).
5. Self-reporting CE-drug use can be seen as sensitive and thus may provoke drop-out, non-response, and underreporting[4] —especially if the anonymity of respondents is not guaranteed (Benotsch et al., 2013; Sattler, in press). This undoubtedly causes downward-biased prevalence estimates. In our telephone study, it was not possible to employ other measures such as testing hair, urine, or blood and contrast these results with self-report measures. But individuals might be reluctant to allow such tests (cf. N'Goran et al., 2014), which can thus also lead to distorted prevalence estimates due to selection bias. We did, however, inform the participants verbally and in writing about the measures to ensure the anonymity of their participation. Our results also show that item-nonresponse was considerably low (0.15% for prior CE-drug, and 1.89% for the willingness measure), which can be one indication of relatively low perceived sensitivity of the question resulting in a high confidentiality of answering (Sattler et al., 2013a). We calculated all models with raw data and after applying the multiple imputation procedure to test whether dropout and item-nonresponse affected our results. Our analysis show that the results are highly similar (see Tables S2, S3), which testifies to the robustness of our results.
6. Due to the low prevalence of CE-drug use, we only employed a lifetime prevalence measure of CE-drug use. However, future studies should distinguish periods of use (e.g., the 1-month or 12-months prevalence) more precisely, investigate frequency measures (e.g., to differentiate between regular use and one-time use), assess the dosage (e.g., to assess the severity of misuse), run drug-specific analyses, and investigate single- and poly-substance use (Turiano et al., 2012; Sattler and Wiegel, 2013; N'Goran et al., 2014; Sattler, in press) to further increase our understanding of the association between BFI and CE. As a second outcome variable, we probed the respondents about their potential future use of CE-drugs in general. Future studies could detail this by assessing willingness for specific situations and in specific contexts (e.g., in high stress situations). Such measure can be developed also in order to differentiate between behavioral willingness and behavioral intentions, e.g., in order to test the Prototype-Willingness Model (Gibbons et al., 1998a,b, 2009; Gerrard et al., 2006).
7. Another caveat of our research is associated with the use of cross-sectional data, implying that conclusions about the causal effect of personality are not warranted. Some scholars argue that drug use may cause changes in personality traits (Caspi et al., 2005; Normann and Berger, 2008; Kipke et al., 2010). Following this argument, the associations between the personality traits investigated and CE-drug use could be at least partially explained by drug-induced personality changes. To our knowledge no such research exists (yet) for CE-drug use, but it does for other substances (Bates and Pandina, 1991; Littlefield et al., 2010; Hicks et al., 2012; Hulka et al., 2015)

[4]Over-reporting might occur in rare cases, but it is assumed to be less likely in our context since most people in prior studies voiced moral objections to using CE-drugs Sattler et al., 2013a,b; Schelle et al., 2014; Wiegel et al., 2015.

and it could be assumed that such effects are possible for CE-drug use as well. On the other hand, it has been argued that personality traits are relatively stable entities (Costa and McCrae, 1988; Soldz and Vaillant, 1999; Caspi et al., 2005; Terracciano et al., 2006; Turiano et al., 2012) and it has been assumed that they might not change rapidly through CE-drug use (Metzinger, 2012; Wulf et al., 2012), whereas some research has shown trait changes for other substances after as little as a few weeks or months (Tang et al., 2009). One study has shown that personality still had predictive power if there was a long time-lag between the assessment of personality and substance use (Turiano et al., 2012). But this study also found that personality changes affected substance use. These findings call for more longitudinal research to assess the covariation of personality and CE-drug use or substance use in general over time (Sher et al., 2000; Turiano et al., 2012; N'Goran et al., 2014). However, our results show that the associations found between the willingness measure and the personality traits was similar for non-users and users. Thus, those who did not experience any potential personality changes from CE-drug use did not show a different willingness to use such drugs, which corroborates the effects on prior CE-drug use we found for personality traits. But still, our assessment of prior use did not cover the frequency, dosage, or duration of use, which can be seen as affecting substance-induced personality change. In addition, unmeasured confounder variables (such as genetic dispositions or social capital) could influence both personality and substance use, or personality could be influenced by these kinds of third variables, mediating their effect on substance use (Eysenck, 1999; Malouff et al., 2007; Schunck, 2014). Taken together and according to the reasoning of Malouff et al. (2007) on alcohol consumption, it is possible that (a) personality leads to CE-drug use, (b) CE-drug use leads to certain personality traits, (c) a third variable influences both, (d) personality mediates the effect of a third variable, or e) a combination of these effects is operating. Studies investigating these possibilities should also investigate variables that might influence the relationship between personality traits and CE-drug use, such as stress, social pressure, etc. (Francis, 1996; Benotsch et al., 2013). Data allowing such investigations do not currently exist.

This exploratory study investigated how prior and future CE-drug use and the Big Five traits are associated. To better understand its findings and those of earlier studies on the Big Five traits and various substances used for CE and other purposes, future research should put more emphasis on developing a coherent theoretical model. To test this model, more highly elaborated and fine-grained measures should be employed in order to challenge the robustness of our findings and obtain a more thorough comprehension of the relationship.

Conclusion

This large-scale study is based on a random sample of employees in Germany and shows that the use of prescription drugs to augment cognitive performance among healthy individuals is an empirical reality. However, this behavior is less widespread than had been anticipated by many scholars and media reports. But the significantly greater willingness to use CE drugs compared to the lifetime prevalence may be indicative of a possible increase in CE-drug use in the future. Still, the extent to which willingness to use CE drugs translates into actual behavior must be addressed in longitudinal studies. It remains to be discussed which threshold of willingness and prevalence justifies further prevention and regulation means. At the very least, a non-negligible number of individuals already risks side-effects, long-term health consequences, and the involvement of the criminal justice system by using often non-efficient pharmaceutical agents. These individuals may also contribute to pressuring others to use such drugs, to increasing healthcare costs, and to other issues discussed in the ethics debate (e.g., CE-drug use in relation to the authenticity of users, fairness, or social inequality). This study increases our understanding of potential psychological factors that hamper or foster the use of CE drugs. We found that high levels of conscientiousness were associated with decreased retrospective/prospective consumption, while high levels of neuroticism increased it. Such insights about personality profiles could be used to inform the development of treatment approaches tailored to these profiles in order to minimize health problems (Booth-Kewley and Vickers, 1994; Terracciano et al., 2008; Conrod et al., 2011). Another approach would be to develop interventions to promote beneficial personality traits (e.g., increasing conscientiousness) and thereby support a positive change toward health-related behaviors in general (Magidson et al., 2014; Hudson and Fraley, 2015). However, less risky options for enhancing one's cognitive performance (such as sufficient sleep, seeking support, meditation, physical exercise) should be promoted for those who want or must enhance their performance (e.g., Bostrom and Sandberg, 2009; Dresler et al., 2013; Maier and Schaub, 2015; Wiegel et al., 2015).

AUTHOR CONTRIBUTIONS

Wrote the Paper: SS, RS. Analyzed the data: RS.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2015.01971

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Neuroenhancement and the strength model of self-control

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Neuroenhancement (NE), the use of substances as a means to enhance performance, has garnered considerable scientific attention of late. While ethical and epidemiological publications on the topic accumulate, there is a lack of theory-driven psychological research that aims at understanding psychological drivers of NE. In this perspective article we argue that self-control strength offers a promising theory-based approach to further understand and investigate NE behavior. Using the strength model of self-control, we derive two theory-driven perspectives on NE-self-control research. First, we propose that individual differences in state/trait self-control strength differentially affect NE behavior based on one's individual experience of NE use. Building upon this, we outline promising research questions that (will) further elucidate our understanding of NE based on the strength model's propositions. Second, we discuss evidence indicating that popular NE substances (like Methylphenidate) may counteract imminent losses of self-control strength. We outline how further research on NE's effects on the ego-depletion effect may further broaden our understanding of the strength model of self-control.

Keywords: ego depletion, neuroenhancement, self-control, self-regulation

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Introduction

A survey recently published in *Nature* revealed that one out of five respondents admitted having previously used substances as a means to enhance cognitive performance (Maher, 2008). The results of this survey fueled considerable research activity in the field of this so called *Neuroenhancement* (NE). We understand NE as a behavior that occurs within a defined means-end relation. This means a substance is being used as a means to enhance cognitive performance (Wolff and Brand, 2013; Wolff et al., 2014). *Drug Instrumentalization Theory* (DI-Theory) proposes that the means-end relationship that underlies such non-addictive drug use can be understood as a two-step process: "(1) the seeking and consumption of a psychoactive drug in order to change the present mental state into a previously learned mental state, which then allows for, (2) better performance of other, previously established behaviors and better goal achievement" (Mueller and Schumann, 2011). Understanding NE from the perspective of DI-Theory, an individual uses a substance with the aim of changing his or her current mental state (e.g., being tired and not concentrated) into a more desirable state (e.g., being alert and able to focus), which then allows for better performance. From a psychological perspective it is not important if the chosen substance is actually effective in enhancing performance. The assumed functionality attributed to a substance is seen as the driving force behind NE behavior (Wolff and Brand, 2013; Maier and Schaub, 2015). NE has therefore been defined as a healthy individuals' use of (psychoactive) substances under the assumption of these substances being functional means in order to enhance his or her already proficient cognitive capacities (Wolff et al., 2014).

Depending on what type of substances are subsumed under the NE concept by the extant research on NE, the reported prevalence rates vary to a great extent. Lifestyle drug NE (e.g., Red Bull) is the most prevalent with reported rates as high as 89% (Mache et al., 2012). Prescription drug NE (e.g., Ritalin) and illicit drug NE (e.g., Speed) are reported at much lower rates of well below 10% (e.g., McCabe et al., 2005, 2012; Teter et al., 2006). However, the real prevalence rates for prescription drugs and illicit substances NE may be much higher as social desirability is likely to bias the results: Using randomized response techniques, the 1 year prevalence rate of prescription drug NE has for example been found to be as high as 20% (Dietz et al., 2013). In our further discussion of NE, we follow the behavioral definition of NE and subsume all three variants (i.e., lifestyle drug, or soft; Maier and Schaub, 2015, prescription drug and illicit drug NE) under the NE concept.

The potential negative effects of lifestyle NE substances on health are mostly unknown to the general public (Rath, 2012). For instance, high levels of caffeine and sugar in lifestyle products can be associated with nervousness, headaches, and tachycardia (Clauson et al., 2008). Even caffeine related deaths have been reported (Clauson et al., 2008).

The high prevalence rates (e.g., McCabe et al., 2005, 2012; Teter et al., 2006) and the potential negative health consequences (e.g., Clauson et al., 2008; Rath, 2012) that are associated with the most frequently used drugs underline the necessity to get a better understanding of *why* individuals start and/or *continue* to neuroenhance. However, past research on NE has been mostly conducted rather unsystematically, as for instance psychological correlates of NE behavior have been collected mostly in an explorative manner as part of epidemiological approaches at the expense of theory-driven, experimental approaches (e.g., Weyandt et al., 2009; Mache et al., 2012). As an exception, one recent study applied the *strength model of self-control* (Baumeister, 2003; Baumeister et al., 2007) to predict first time NE behavior in an experimental setting (Wolff et al., 2013). While not explicitly focused on NE behavior, another experiment has investigated the effect of Methylphenidate (a substance commonly used for NE) on self-control strength (Sripada et al., 2014). Finally, a very recent field study investigated the relationship of trait self-control strength and doping intentions (Chan et al., 2015). Based on the few theory-driven approaches to NE, self-control strength (or self-control demanding situations) seems to play an important role in NE behavior. We therefore think that the relationship between self-control and NE (and other forms of drug instrumentalization) warrants further investigation. We will explain our theoretical assumptions in more detail in the following sections.

The Strength Model of Self-control

Self-control describes the ability to volitionally regulate ones' behavior or predominant response tendencies in order to achieve a desirable goal (e.g., Baumeister et al., 1994, 2007). For instance, while being on a diet one has to resist tempting but high caloric drinks or snacks in order to achieve the long term goal of losing weight (e.g., Kahan et al., 2003). However, self-control does not always work and the strength model of self-control offers a potential explanation for lapses in self-regulatory behavior (Baumeister et al., 1998). According to Baumeister et al. (1994) all self-control acts (e.g., emotion regulation, persistence) are empowered by one global metaphorical resource. There are inter-individual differences in the capacity of this resource as some individuals are more adept in regulating themselves than others (i.e., trait self-control strength; e.g., Tangney et al., 2004). In general, this self-control strength has a limited capacity meaning that it can become temporarily depleted after having exerted self-control strength, which is a state labeled *ego depletion* (i.e., state self-control strength; e.g., Muraven and Baumeister, 2000). In a state of ego depletion self-control deficits are more likely to occur as there is less self-control strength available to volitionally regulate ones' behavior (cf., Muraven and Baumeister, 2000). The effect of ego depletion is not domain-specific, meaning that previous acts of self-control in one domain (e.g., thought regulation) can have a negative carry-over effect on self-control performance in other, seemingly unrelated domains (e.g., emotion regulation; cf., Englert and Bertrams, 2013). Previous research has found a reliable effect of ego depletion on subsequent self-control performance as Hagger et al. (2010) report a medium-to-large effect of ego depletion on subsequent self-control in their meta-analysis.

Important for the present paper is the finding that under ego depletion individuals have a tendency to fall back onto their dominant behavioral tendencies (Govorun and Payne, 2006). For instance, restraint eaters are more likely to consume candy under ego depletion (Kahan et al., 2003; Hofmann et al., 2007) and in the same vein at-risk drinkers are more prone to relapses in a state of ego depletion (Ostafin et al., 2008).

Self-control and NE

The strength model of self-control (e.g., Baumeister et al., 1994) allows for theoretically derived hypotheses regarding the self-control-NE relationship. Based on the strength models' predictions and the existing empirical evidence (e.g., Hagger et al., 2010) this relationship does not seem to be a trivial one. First, NE and self-control seem to be associated in a reciprocal fashion: Self-control strength is associated with NE behavior (e.g., Wolff et al., 2013) and NE substances may also affect the availability of self-control resources (Sripada et al., 2014). Second, they seem to be associated both on a macro and on a micro level: On a macro level, trait differences in self-control are associated with differences in functional (e.g., doping in sports) and non-functional (e.g., illicit drugs) substance abuse (Chan et al., 2015). On a micro level, temporary depletion of self-control resources affects decisions to consume substances as a function of one's history with such substance use behaviors (Wolff et al., 2013). In the following we will discuss these propositions in more detail.

Self-control Resources Affect NE Behavior

As previously mentioned, individuals have a tendency to follow their regular habits or behavioral tendencies in a state of ego depletion (Govorun and Payne, 2006). Govorun and Payne found out that participants in a state of ego depletion were more likely to rely on their automatic behavioral tendencies which in that case

was the tendency to rely on their stereotypes (i.e., an automatically activated response tendency) in a decision task. On the contrary, participants with temporarily available self-control strength were more likely to suppress their stereotypes and to respond in a more desirable manner.

Based on these findings, ego-depletion should thus differentially affect NE behavior as a function of one's history with NE. If depleted, a regular user would be expected to neuroenhance as it is his or her dominant behavioral response tendency. This prediction is in line with the stereotypical image of an overwhelmed student who takes Ritalin® to meet an assignment deadline or a manager who—before an important meeting—takes cocaine to perform better. However, for first-time NE users the predictions are reversed: If one has never used NE before, ego-depletion is predicted to elicit the dominant behavioral response which would then be to abstain from using a substance. This second prediction was investigated in a recent experiment (Wolff et al., 2013): Participants who had no history with NE were randomly assigned to a depletion or a non-depletion condition. After having worked on either a depleting or a non-depleting task, they were then informed that they would be asked to complete a cognitively demanding task after a short break. In this break they were given the opportunity to potentially enhance their performance with a caffeinated granulate. In line with the theoretical predictions, the depleted participants were actually significantly less likely to use the provided substance. So in this study, higher levels of state self-control strength were actually associated with a higher tendency to use NE to improve performance, indicating that higher levels of self-control strength were rather negative. This underlines the importance of self-control resources in the decision to neuroenhance for the first time and invites further research on the self-control-NE relationship. Most importantly, thus far the prediction that depletion leads to NE in habitual users has not been investigated and needs to be tested in future studies.

Chan et al. (2015) recently investigated how trait self-control strength is associated with athletes' attitudes toward doping and the intentions of using substances to improve athletic performance. The authors found out that athletes with lower levels of trait self-control strength were more likely to have a heightened attitude and intention toward doping in general, and a reduced intention, behavioral adherence, and awareness of doping avoidance. Even though this study did not test how temporary levels of self-control strength affect actual NE behavior it gives a first indication that trait self-control strength also plays an important role in the self-control-NE relationship that needs to be investigated in more detail.

NE Substances Can Affect Self-control Resources

In the previous section we discussed the complex relationship of ego depletion and the likelihood to use NE as a function of one's NE experience. However, NE use may also be an adaptive behavior as it may help to replenish depleted self-control strength more quickly. A recent study investigated the effects of a popular NE substance on state self-control strength (Sripada et al., 2014). Specifically, the study revealed that Methylphenidate was effective in preventing ego-depletion states in an experimental setting. Participants from a Methylphenidate condition that had performed a primary self-control task did not display the typical impaired performance in a second self-control task, while participants from a control condition that did not consume Methylphenidate showed the typical ego depletion effect. Even though Sripada et al. (2014) did not explicitly focus on NE, their study gives an indication that some NE substances may alleviate ego depletion effects. This is important, as alleviation of depleted self-control strength might be a mediating variable in the subjective effectiveness individuals assign to an NE substance. This alleviation potential may thus be one explanation for the popularity of certain NE substances. Further, this research shows that self-control and NE seem to be associated in a bidirectional way. However, thus far it has not been sufficiently investigated how NE and ego depletion are interrelated. More research is needed to investigate how and why NE substances can replenish one's self-control strength and how this potentially affects further NE behavior.

Discussion

In the present paper, we argued for a theory-driven approach to investigate NE as thus far research in this field has been mostly conducted explorative. We identified the strength model of self-control (Baumeister et al., 1998) as a promising candidate theory. Self-control and NE seem to be interrelated in a bidirectional manner: Self-control resources affect the initiation of NE behavior depending on one's personal NE experience (Wolff et al., 2013). Trait self-control strength is also related with one's attitude toward NE and the intentions of consuming NE (Chan et al., 2015). NE substances can also affect the availability of self-control resources as certain substances may lead to a quicker revitalization of depleted self-control strength (Sripada et al., 2014). We reviewed research that can be seen as a first step to investigate both directions and outlined further research questions that would allow for theory-driven experimental research on NE.

The ethical verdict and policy implications on NE are still heavily debated (e.g., Farah et al., 2004; Greely et al., 2008; Forlini and Racine, 2009). The goal of this article was not to take a side in this debate as we do not recommend taking certain substances to replenish depleted self-control strength. We rather wanted to provide a theoretical backdrop for conducting psychological research on the initiation and the effects of NE. We are convinced that the complex relationship of NE and self-control warrants further investigation and will allow for a deeper understanding of this behavioral trend.

Author Contributions

CE and WW substantially contributed to the writing of the manuscript. Both authors approve the final version of the manuscript. The authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Australian University Students' Coping Strategies and Use of Pharmaceutical Stimulants as Cognitive Enhancers

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Background: There are reports that some university students are using prescription stimulants for non-medical 'pharmaceutical cognitive enhancement (PCE)' to improve alertness, focus, memory, and mood in an attempt to manage the demands of study at university. Purported demand for PCEs in academic contexts have been based on incomplete understandings of student motivations, and often based on untested assumptions about the context within which stimulants are used. They may represent attempts to cope with biopsychosocial stressors in university life by offsetting students' inadequate coping responses, which in turn may affect their cognitive performance. This study aimed to identify (a) what strategies students adopted to cope with the stress of university life and, (b) to assess whether students who have used stimulants for PCE exhibit particular stress or coping patterns.

Methods: We interviewed 38 university students (with and without PCE experience) about their experience of managing student life, specifically their: educational values; study habits; achievement; stress management; getting assistance; competing activities and demands; health habits; and cognitive enhancement practices. All interview transcripts were coded into themes and analyzed.

Results: Our thematic analysis revealed that, generally, self-rated coping ability decreased as students' self-rated stress level increased. Students used emotion- and problem-focused coping for the most part and adjustment-focused coping to a lesser extent. Avoidance, an emotion-focused coping strategy, was the most common, followed by problem-focused coping strategies, the use of cognition on enhancing substances, and planning and monitoring of workload. PCE users predominantly used avoidant emotion-focused coping strategies until they no longer mitigated the distress of approaching deadlines resulting in the use of prescription stimulants as a substance-based problem-focused coping strategy.

Conclusion: Our study suggests that students who choose coping responses that do not moderate stress where possible, may cause themselves additional distress and avoid learning more effective coping responses. Helping students to understand stress and coping, and develop realistic stress appraisal techniques, may assist students in general to maintain manageable distress levels and functioning. Furthermore, assisting students who may be inclined to use prescription stimulants for cognitive enhancement may reduce possible drug-related harms.

Keywords: prescription stimulants, cognitive enhancement, stress, coping, university students

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INTRODUCTION

Background

The non-medical use of prescription stimulants by healthy individuals to enhance alertness, focus, memory, mood and other cognitive functions (Hildt and Franke, 2013) has been dubbed 'pharmaceutical cognitive enhancement' (PCE) by some bioethicists. The stimulants commonly used for PCE include those used to treat Attention Deficit Hyperactivity Disorder, such as Ritalin, Concerta or Adderall, and wakefulness promoting agents used to treat Narcolepsy, for example Modafinil (Repantis, 2013). There is some evidence that some university students are using these stimulants for PCE purposes (Bavarian et al., 2013; Mazanov et al., 2013; Singh et al., 2014; Ram et al., 2015). The assumption commonly made in ethical analyses of this practice is that PCE helps students to manage the performance demands of university life.

Although the prevalence of PCE is reported to vary widely between countries and institutions, it is often discussed as if it were very common in all academic and professional environments (Maier and Schaub, 2015). Australian studies have found low rates of (lifetime) PCE use in the general population at 2.4% (Partridge et al., 2012) and university students with an average of 1.4 to 4.4% for 'study' and/or 'study only' purposes (Mazanov et al., 2013). Discussions of prevalence and purported demand for PCE in academic contexts have been based on incomplete understandings of student motivations, and often based on untested assumptions about the context within which stimulants are used (Lucke et al., 2011; Zohny, 2015).

Many of these assumptions focus on the academic aspects of university life, such as improving grades, increasing or maintaining academic competitiveness, improving the ability to learn, and self-medicating for difficulties studying (Greely et al., 2008; Rabiner et al., 2009; Lucke et al., 2013). Much of the research focusing on student use of stimulants has focused on identifying the prevalence of prescription stimulant use, assuming that all stimulant use is motivated by the desire to enhance cognitive performance (Greely et al., 2008). Motives for PCE use may also incorporate recreational and lifestyle purposes (Partridge, 2013). In one of the only studies to report on the context of student prescription stimulant use, Hildt and Franke (2013) argue that "if one takes the users' overall life situation into consideration, it seems that [they] perceive stimulants at least partly as beneficial for leading an 'active life' without being focused too much on academics" (Hildt et al., 2014). These findings call for a better understanding of the psychological and social factors that influence the use of prescription stimulants by university students for putative PCE purposes. Indeed, reasons for using stimulants as PCEs may encompass more than academic goals; they may also represent attempts to cope with biopsychosocial stressors in university life and to offset students' inadequate coping responses, which, in turn, may affect their cognitive performance.

Coping Strategies

Stressors are situations or events that people perceive to be threatening to their physical, psychological, or social health, and may be acute or chronic. *Coping* refers to efforts to successfully navigate the challenges presented by stressors and alleviate associated distress (Snooks, 2009). Lazarus and Folkman identified that there are two common coping responses, *problem-focused* and *emotion-focused coping* (Lazarus and Folkman, 1984). Either or both of these coping responses represent a variety of coping strategies and can be applied in any given situation. The major difference between the two is whether or not the chosen coping response directly moderates the stressor. **Figure 1** briefly illustrates Lazarus and Folkman's theory of choosing a coping response (Lazarus and Folkman, 1984).

Proactive coping refers to actions that prevent or minimize exposure to known stressors (e.g., developing good sleep, exercise, and nutritional habits) (Snooks, 2009). If a stressor cannot be prevented or minimized with proactive coping habits (e.g., sleep is interrupted by worry over deadlines leaving the person tired and prone to stress), it is appraised to determine what type of response is needed to minimize distress. There are two stages to appraisal; primary and secondary appraisal. Primary appraisal asks "what does this potential stressor mean to me?" which determines if the stressor is benign. If it is not benign, the secondary appraisal involves asking "what can I do?"

As new information about the stressor is acknowledged (e.g., realizing that an assessment will take more time to complete than first thought), reappraisal evaluates alternative responses and their perceived effectiveness to manage distress. Reappraisal is often cyclical as new information about the stressor comes to light, thus a review of the stressor and the evaluation of potential coping strategies is repeated (Snooks, 2009).

Problem-focused coping aims to directly manage a stressor to reduce distress. This response is effective when an individual has the ability to moderate the stressor (e.g., by starting an assignment earlier to reduce distress as the deadline nears). *Emotion-focused coping* aims to cope with the emotions and feelings aroused by the stressor. This response may be chosen when it is not possible to change or moderate the stressor itself (e.g., seeking social support when you are disappointed with an assessment grade that cannot be changed). Avoidance is a common emotion-focused response that allows temporary respite from the stressor, but at the cost of prolonging or amplifying distress (Snooks, 2009; Taylor, 2012). It is important to note that both coping responses can be helpful in particular situations and that there is not one coping strategy that is better at managing distress across all situations (Snooks, 2009).

Previous studies investigating stress and coping strategies of college students generally found that students' perception of stress could predict their coping behavior (Kariv and Heiman, 2005), and that emotion-focused avoidant coping was more dominant than problem-focused coping. Some variables that mitigate the stress/coping relationship in previous studies are related to (1) gender, where masculinity is associated with problem-focused coping and femininity correlates with emotion-focused coping (Dyson and Renk, 2006; Brougham et al., 2009),

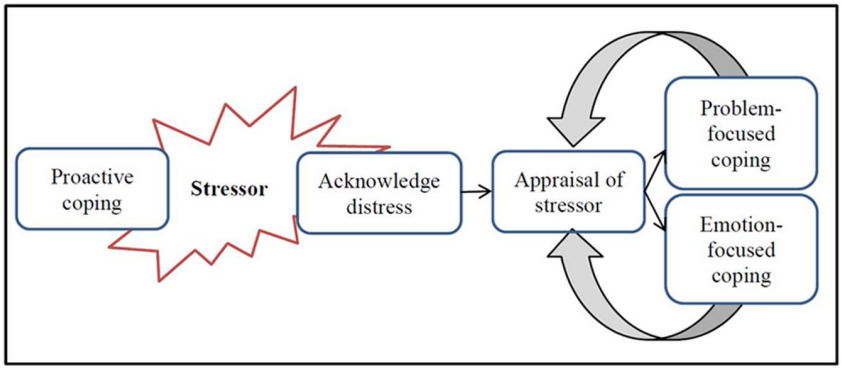

FIGURE 1 | Lazarus' model of stress, appraisal, and coping.

although studies vary on this finding; (2) age, particularly 1st-year students (Kariv and Heiman, 2005; Dyson and Renk, 2006) where coping skills improve with practice and age (Snooks, 2009); and, (3) support, especially for those living away from family and friends during their studies (Dyson and Renk, 2006). Overall, improving coping behaviors, in particular problem-focused coping, appears to reduce depression symptomology (Steinhardt and Dolbier, 2008) and improve students' academic grades (MacCann et al., 2011).

A lack of effective coping experiences and skills may mean that younger people are not as effective at choosing the most helpful coping responses to the demands of student life. Young people may also be more inclined to choose coping strategies, such as the use of PCEs to help manage distress where other coping strategies are overlooked or ineffective. The findings discussed in this paper are a part of a broader qualitative study investigating factors in the academic, psychological and social context that influence students' interest in, and approaches to cognitive enhancement (including non-PCE methods).

Study Aims

Here we explore our interview data to understand how students coping strategies may be related to PCE use, and how cognitive enhancement behaviors may be explained by current coping theories. We analyzed perspectives of university students on the demands of student life with the aims of identifying (a) what strategies students adopted to cope with the stress of university life, and (b) to assess whether students who have used PCEs exhibit particular stress or coping patterns.

MATERIALS AND METHODS

Participants and Recruitment

Ethics approval for this study was obtained from the University of Queensland in accordance with the National Statement on Ethical Conduct in Human Research (Australia). We recruited students aged 18–24 that were actively enrolled in university courses. Participants were recruited for a research study about students' study and health habits in several ways including: direct approach; posting flyers around campus noticeboards; the university's online student blackboard; and, snowballing. A second round of purposive advertising was carried out to diversify the sample and recruit additional PCE users by modifying the advertisements to include "study drugs". Approximately 250 students were screened in this second step to include more diversity in the use of caffeine, drugs, alcohol, and especially PCE use. Participants were compensated for their time with a $20 Coles Myer gift card. Recruitment ceased once there were no new themes emerging from the interviews and data saturation was achieved.

Procedure and Materials

Participants were first asked to complete a 12-item demographic survey about: sex; age; residential postcode; Australian residency; ethnicity; caring responsibilities; years at university; current degree; host university; study-load; grade point average of previous semester; and, hours of paid employment per week. All interviews were digitally recorded to MP3 files and independently transcribed. We removed any identifying information and replaced the participant's name with a number. Prior to commencement of the interview, participants were given an information sheet describing the study, what they would be required to do, and their rights as a participant. Interviews were conducted in 2013 by two members of the research team (CJ, CF).

The interview schedule focused on students' experience and attitudes toward studying and how they manage the demands of student life. Questions were open-ended so that participants were able to provide more detailed responses and then prompted by the interviewer if more information was required. The semi-structured interview schedule consisted of several domains of interest: educational values (*"Why is it important for you to get an education?"*); study habits and achievement (*"Can you describe what your study habits look like?"* and *"What do you think makes a successful student?"*); stress management *("How do you manage stress when you are studying?"*); getting assistance *("Where would you get support if you needed it?"*); competing activities and responsibilities *("Do you find yourself compromising other areas of your life to study, or do you compromise your study to do other things?"*); health habits *("What do you sleep patterns look like?"*);

and cognitive enhancement *("Do you consume other things that help you stay alerts, concentrate or study?")*.

Data Analysis

Interview transcripts were analyzed using NVivo qualitative data analysis Software (QSR International Pty Ltd. Version 10, 2012). Each transcript was read by two investigators (CJ, CF) to identify errors in transcription and remove identifying information. An inductive approach to thematic analysis was used to code student responses. The initial analysis identified patterns in how students coped, including the use of PCEs, which emerged as a coping response. A more focused analysis was carried out to identify different patterns of coping between PCE users and non-users. **Table 1** displays the coding structure for coping-related strategies. 'Sources' represent the number of participants who referenced the respective theme, and 'references' denote how many times the collective sample of participants referenced a theme, that is, one source may reference a particular theme or content multiple times.

During the interview, students were asked about their level of perceived stress and their perceived coping ability. A 5-point Likert scale (1 = lowest and 5 = highest) was used and then graphed in scatterplot form (refer **Figure 2**). Due to multiple data points overlapping and reducing the visual plotting of data points, scores were 'jittered' (Marinsek, 2015) by adding a random number between the range of −0.1 to 0.1 to visually indicate multiple data points.

RESULTS

We recruited 38 full-time university students with a mean age of 20.95 years (ranging from 18 to 24 years), with more females ($n = 22$) than males. The majority were Australian residents ($n = 28$), with the balance of international students originating mainly from America or Asia. **Table 2** displays demographic information about the students in this sample.

The students interviewed displayed a negative relationship between their ability to cope with the demands of study and the level of stress that they reported experiencing. **Figure 2** displays students' self-rated stress in relation to their self-rated coping levels. Students, who rated their ability to cope with stress as high, reported less stress than those who reported low coping ability. There were five students who had previous experience using PCEs, of which four were repeat users. The four repeat PCE users rated higher stress levels and lower coping ability than average.

We identified different ways that students reported coping with the pressure of study and managing stress to explain the correlation in **Figure 2**. Each student might use a combination of coping strategies but generally followed a dominant strategy. Through the thematic analysis of the interview transcripts, we identified two major coping themes, and one minor coping theme (see **Table 1**). These were, respectively: emotion-focused coping; problem-focused coping; and, adjustment-focused coping.

TABLE 1 | Thematic coding of coping strategies.

Coping theme	Sources	Reference
Emotion-focused coping	34	105
Avoidant	32	83
Social support	12	18
Switch tasks	3	4
Problem-focused coping	34	80
'Cognition enhancing' substances	28	50
Planning, organizing and monitoring	16	24
Exercise/sports/recreation	4	4
Academic support	2	2
Adjustment-focused coping	8	10
Self-awareness/acceptance of limitations	6	7
Perspective	1	1
Spirituality	1	2

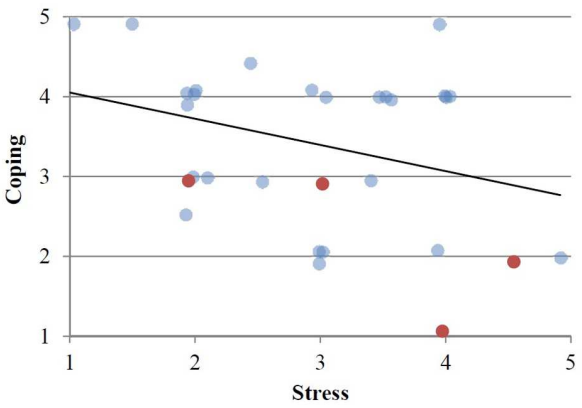

FIGURE 2 | Self-rated stress and coping levels. Red markers indicate repeat PCE users. Bold line denote trendline.

TABLE 2 | Sample demographics.

Item	Males	Females	Combined average	Total
Sex	16	22	–	38
Mean years of age	20.8	21.1	21	–
International student	2	8	–	10
Average years at university	1	2.5	1.75	–
Average GPA	5.2	5.6	5.4	–
Employed weekly	11	17	–	28
Average self-rated stress	2.7 (0.98)	2.9 (1.1)	2.8 (1.0)	–
Average self-rated coping	3.7 (0.96)	3.4 (1.2)	3.5 (1.1)	–
PCE users	2	3	–	5

Parentheses denote standard deviation of scores.

Emotion-Focused Coping

Emotion-focused coping strategies changed how students felt in the *short-term* when they experienced stress. These included: avoidance; seeking support; and switching activities.

Avoidant Strategies

Avoidant strategies were the most common emotion-focused coping strategy. They involved the selection of activities that allowed students to avoid feelings of distress. The most common avoidant activities were: cleaning, eating, sleeping, checking/updating social media, and socializing.

Some students reported consistent use of avoidant behaviors. For example, *"I probably sleep more because I'm trying to avoid it* [study] *then, or just trying to take my mind off it because it's the only time you don't really think about it"* (11). Others avoided the task at hand with, "*Anything so cleaning the house, surfing the internet, watching movies, going for a walk, cleaning the car, anything*" (03).

Avoidant strategies provided short-term relief by allowing the student to avoid the unpleasant feelings associated with the study task. However, students did not necessarily enjoy the avoidant task, such as Student 27 who commented that: *"It's like – the horrible thing is, I might normally enjoy watching YouTube videos or whatnot, but because I've got stress in the back of my mind, all enjoyment is kind of sucked out of it and it just becomes an avoidant activity*", but this often does not reduce the stress afterward: *"I could be playing browser based games, up to three in the morning. Just could be, just to forget about* [what I have to do], *yeah, and that obviously stresses me out*".

Students often described avoidant strategies as unplanned. The duration of avoidant activities was often uncontrolled, potentially costing the student more time than anticipated. One student explained that: *"Distractions probably go through the roof, just procrastination. Finding other things to do during the break but then the break seems to get longer and longer just because you're really sick of studying all day. . . . It's good to have the relaxation period but then because it goes on for so long you're pressured even more to study even harder and longer"* (03).

Many students who used these strategies also reported that the stress of an approaching deadline motivated them to start study tasks, and that they probably need the distress to get started: *"I'd just rather go out with my friends and do stuff. I knew it was bad and it stresses me out but I still did it. . . . Yeah I work better under pressure I think"* (15).

The students who used PCEs predominantly used avoidant strategies and experienced additional stress when little progress had been made toward meeting a looming deadline. When this strategy no longer worked, Student 29 notes that, *"I usually take it* [Concerta] *like before that* [stress] *happens just so I can start studying. But usually it just gets too close* [to the deadline], *even though I have that and I can study for hours it's still really stressful."*

Social Support

Seeking social support was another emotion-focused coping strategy. Students sought support from friends, family, and peers about how they felt. For example, *"Yeah if I'm having panic attacks and stuff mum will help just calm me down and put things in perspective, because it's just because I get overwhelmed and worried I won't get everything done. . . Yeah or someone to just talk at so I can put all my things in order and then realize I'm okay"* (15).

Seeking support often had a positive outcome because it allayed some of the unpleasant feelings and provided new ways of seeing or approaching the task. Student 35 noted that, "*I guess my family's pretty, like they're all pretty nice, and comforting so just being at home is quite good."* Other types of social support allowed students to get back to the task in a more positive way, for example: "*So I think talking helps . . . So I was really feeling bad afterward because he had to cope with me. But still, afterward you feel better because you talked with somebody about your day and what you still have to do. So that helped me, that somebody is there and says, well yeah, can I help you with that?"* (08).

Switching Activities

Students often described switching activities if their study task was creating stress. This strategy uses a planned or controlled break away from the task to undertake activities that were not designed to progress the task directly but allowed the student to return to the task feeling less stressed. For example: *"I find music really helps with stress, especially if it's – if there's not much I could really do in that situation, like if I just need to alleviate that anxiety I would just listen to music that I like for maybe 10 min and then I get better. Sometimes talking to a friend could work too or just – sometimes when it's really – sometimes you think you don't have time to do anything but then your brain just can't work. I find that during those times it's better to just remove yourself and say okay like take a break, take a walk somewhere and then come back to it"* (06).

Switching activities differed from avoidant strategies because the intention was to relieve mental weariness rather than simply to avoid task-related stress. It was also a short-term strategy that often allowed the student to return to dealing with the stressor sooner. It was therefore more effective in addressing the task than other emotion-focused coping styles that did not moderate the stressor.

Problem-Focused Coping

Problem-focused coping strategies moderate the stressor directly, resulting in better *long-term* management of the stressor. Students described many ways in which they directly managed the stressors in their university lives.

Substance Use

Students were specifically asked if they used particular substances of any kind to help them study. The use of substances with the specific purpose as a study aid was the most commonly referenced problem-focused coping strategy across the sample. **Table 3** lists the substances that students were using to enhance their study performance during the academic semester the interview was conducted. This list does not reflect prior broader experience with substances for PCE or recreational purposes, which is represented in **Table 1**.

These putatively *cognition-enhancing* substances can be seen as a problem-focused coping strategy that allows students to moderate their distress by directly working on study goals. For instance, 'tiredness' was a common obstacle to working on academic tasks. Students reported using substances *". . . if I'm really tired and I have to do something"* (11) or *"if I have an*

TABLE 3 | Substances currently used by university students as a problem-focused coping strategy.

Substance	Sources	Reference
Coffee	11	12
Energy drinks	7	12
Food (chocolate, fruit, juice)	5	6
Tea (black and herbal)	5	6
Caffeine pills	4	5
Prescription stimulants	2	2
Essential oil	1	1
Fish oil supplement	1	1
Total	**28**	**45**

assignment due the next day, I'll buy an energy drink just to stay awake the whole night and make sure I don't fall asleep" (21).

Students were aware of potential cognitive enhancing properties of the substances they used and made a distinction between their use as a study aid and use for other purposes, such as enjoyment or long-term or general health benefits. For example, one participant acknowledged that they used energy drinks "*To help pick me up, not for the taste. I know they're terrible for you, but sometimes you've got to do it, I find anyway*" (34).

Some participants' use of cognitive enhancing substances and dietary supplements, although known for various long-term health benefits, were used specifically for cognition enhancing purposes: "*I just take fish oil – just because of the – I know it's quoting from the neuroethics lecture about drugs that enhance cognition"* (22).

Use of multiple substances was reported by some participants, especially those who were inclined to use prescription stimulants as PCEs or other illicit substances, as Student 24 illustrated: *"So I was using energy drinks for the most part. I managed to for the final semester of my honors I did manage to get a hold of some dexamphetamines – so some ADD medication. . . .Then at the very end I was also using No Doz* [caffeine pills] *as well."*

Planning, Organizing, Monitoring and Reward

Planning, organizing, monitoring and reward were strategies that students used to moderate the stress of study. This allowed students to forecast potential stressors, plan around them and monitor their progress and associated stress. A common theme in planning was being aware of the time required for tasks: *"So if I have a harder assignment I'll start it earlier because I know that it's going to take me longer to figure it out and I give myself more time to stop working for the day and start tomorrow if I get too stressed*" (02).

Organization around tasks improved students' execution by planning when something needed to be done and how long it would take. It also identified the step-by-step process required to complete the task, therefore minimizing distress: *"I plan a lot. So I know – I had a big plan the weeks before exam block, and even during exam block, when I would have to study for the next thing. So I knew when I had to do what. So that way I wasn't like getting to the library and going, what do I have to do now?"* (34).

Monitoring performance and rewarding achievements were another theme that reinforced planning and organizing tasks. One student commented on having a very visual method for monitoring and appraisal of stress and progress: *"Like often I'll leave a pile of things on my desk of what needs to be done when I start studying next and if that pile starts building up I feel stressed about it but if I'm on top of it and I've been doing like my 3 h a day, you know, or something like that I'll feel good about it and I'll be able to take a break and pull back from it and it will make me feel okay about it"* (25).

Reward for achieving task-related goals appeared to be associated with being able to withstand distress created by the task. It also enabled the students to fully enjoy the pleasures deferred without the residual distress of incomplete tasks often mentioned by emotion-focused-avoidant-type students. For example, Student 11 stated that *"A lot of the times I'll say if I get this much done, then I can go to whoever's party on the weekend. Obviously, if I had heaps of work to do, then I can only go for a bit, or I can't go."*

Exercise

Exercise was a minor theme mentioned as a tool to improve cognitive performance. It can be considered a problem-focused coping strategy that improves general and brain health, associated with cognitive improvements, for example, *"I think it just gets the blood flowing and just gets my brain working again, like if I've been just sort of watching videos on the Internet or I've just been on Facebook and my brain's just like* [makes flat sound]*, going for a run really helps kick it back into gear I think"* (33).

Academic Support

Seeking academic support for study-related tasks helped students minimize and alleviate the stress in carrying out the task. This kind of support may not directly soothe or avoid unpleasant feelings about a stressful task, but mitigated the distress associated with the task, which in turn moderated the stressor: *"So if we have an issue we go to* [the college advisor] *and a couple of weeks ago I was just like I'm falling apart, I'm going to rip all my hair out, not good stress management, so she was like look, it's just a weekly thing, if you hand it in a couple of days late that's fine, just get it in. So it wasn't a big deal, she still passed me"* (07).

Pharmaceutical cognitive enhancement users in this sample were aware of the various resources available for support but were more hesitant to seek support from services, peers, or teaching staff. These students noted that either they didn't need extra support or didn't think that they should need extra support: *"I know that I'm a bit smarter than anyone else. . . I should be able to think through my own problems. Yeah, I just feel like I should be able to figure it out myself"* [32], or felt uncomfortable about seeking it, *"I would literally just try to figure it out myself, like I just don't like discussing my study habits or like learning with other people"* (29).

Adjustment-Focused Coping

Adjustment-focused coping was a minor theme. This coping strategy changes the way one thinks about stressors. This coping style takes a more rational/cognitive perspective than the behavioral emotional- or problem-focused coping. Adjustment-focused coping was the least common strategy used by students but some shared lessons on how their perspective on stress had changed during their university studies. For example, one student learned that: "*From that point on I said, it's not worth stressing yourself out because it's not really going to change the quality of your work regardless. So it was very much a conscious thing. So now I don't stress anymore*" (24). Another student spoke about how spirituality helped them to manage stress: "*I try my best to get my spiritual life up with it. I just believe in the degree. I can only plan and do my best, but the final decision is not up to me*" (12).

DISCUSSION

The students in our sample used a range of strategies to manage the stressors in student life. As per Lazarus' model of stress, coping, and appraisal, the majority of coping strategies were aligned with problem- or emotion-focused coping styles (Lazarus and Folkman, 1984). Strategies within these coping styles are similar to those validated in other studies. The most common coping style used by the students in our sample was emotion-focused coping, particularly avoidant coping. This strategy is better suited to dealing with stressors that are not able to be directly moderated. Therefore, it focuses on managing the unpleasant feelings in the short-term caused by the stressor.

Problem-focused coping was also common and was predominantly substance-based or involved planning and monitoring strategies. This form of coping focuses on changing the stressor directly thereby reducing some of the distress associated with the completing the task. This strategy is generally better suited to stressors that can be directly moderated, therefore managing stress in the long-term by reducing the challenge presented by the stressor.

Adjustment-focused coping was a minor theme in our data with self-awareness and acceptance of limitations being the most common strategy in this theme. This strategy does not directly seek to relieve unpleasant emotions or moderate the stressor itself. It changes the perception of task-related distress without behavioral action, as emotion- and problem-focused strategies do. A majority of studies on coping have looked at emotion-focused coping or problem-focused coping and few studies review a third coping strategy such as this. It is unclear if this type of coping is a subset of the two dominant strategies, or rather an aspect of the appraisal function as in Lazarus' model of stress, coping and appraisal.

We observed that students often used more than one style of coping for a stressor but exhibited a dominant strategy of coping. The dominant strategy was used until the stressor dissolved or until the strategy no longer minimized the distress, at which point reappraisal suggests that a new strategy needed to be employed. This process generally resulted in the use of more problem-focused strategies as the student context requires that some tasks had to be tackled (i.e., successfully navigating the challenges of the stressor). We found that the coping strategies of the regular PCE users in this sample were dominated by emotion-focused coping. Avoidant coping strategies were used until they no longer minimized distress at which point an alternative approach was chosen, such as using PCEs.

Understanding the behavioral cycle of anxiety may help explain the avoidant coping strategies students frequently adopt to manage the demands of study. Allport noticed a cycle of distress in which avoiding distress became a self-maintaining behaviour independent of the stressor (Allport, 1937; Seif and Winston, 2014). Students using emotion-focused avoidant coping responses often found some short-term relief from stress by focusing on the feelings aroused by the stressor. This, in turn, encouraged them to use avoidance coping strategies in the future.

However, avoidant coping does not diminish the original stressor so the cycle repeats as feelings of distress resurface (i.e., assessments still need to be completed). While this coping response is maintained, students miss opportunities to develop other strategies that may reduce distress more effectively. Students who are coping in more problem-focused ways use longer-term coping responses and dimish distress, subsequently reducing the original stressor's challenge and reinforcing problem-focused coping strategies.

Using PCEs may be a way to directly moderate the stressor and facilitate work on their task. Although this may be perceived as an effective way to directly moderate the stressor (that is, a problem-focused coping strategy), it may not be a healthy long-term strategy. The increased prescribing of ADHD medications over the last decade in Australia has opened up the potential for diversion or normalization of prescription stimulants use in society (Kaye and Darke, 2012). Kaye and Darke (2012) report that many users obtain prescription stimulants from friends with prescriptions. Whilst there is a lack of consensus about the efficacy of prescription stimulants to enhance cognition in healthy individuals, there is better evidence for their adverse side-effects and abuse potential (McCabe and Teter, 2007; Weyandt et al., 2013).

To our knowledge, previous studies have not used health-psychology to understand PCE practices. Further studies investigating the relationship between coping and PCE use would be informative. Specifically, further investigation is required to understand if adjustment-focused coping is a subset of appraisal, such as to what extent do students perceive that they have control over potential coping responses and the capacity to moderate the stressor (i.e., "what can I do?").

Limitations

Given that there is some overlap between emotion- and problem-focused coping and both can alleviate distress and moderate the stressor our categorisation of PCE as problem-focused coping would benefit from further confirmation. For example, one student may use PCEs to work directly on an assignment but PCEs may also improve mood, which in turn makes it easier to work on a task (Vrecko, 2013). In this study, we defined coping

styles based on the responses to stressors rather than the outcome of the response. This is in line with the behavior-oriented coping strategies in Lazarus' model of stress, appraisal, and coping, which does not seek to identify a correct coping response. Instead, it attempts to find the most effective coping response to the stressor in its situational context.

There are some methodological aspects of this study that limit the generalizability of the results. There was a time limit on interviews of 1 hour. In order to collect a breadth of data, some topics were not discussed in depth. It is also unclear how broadly the results apply to the larger population of university students.

This study included a small number of PCE users. We attempted to increase the number by screening approximately 250 students to find more PCE users, however, our findings our findings are consistent with the only two other Australian studies that have found low rates of PCE prevalence in the general population (Partridge et al., 2012) and university students (Mazanov et al., 2013).

CONCLUSION

We interviewed 38 university students, five of whom had experience using PCEs, about how they managed the demands of student life. We found that students who rated higher stress generally rated lower coping ability. The students in this sample used a range of strategies to manage the stress of student life. Both emotion- and problem-focused coping were styles students used to manage stress in their everyday life, often preferring one over the other until it no was longer effective at minimizing stress.

Pharmaceutical cognitive enhancement users reported higher levels of stress and lower levels of ability to cope than the sample average. They preferred to use avoidant emotion-focused coping strategies until they were close to deadlines where they then used stimulants as a problem-focused alternative coping strategy to moderate their stress. This may expose PCE users to additional health harms that may arise from the regular use of prescription stimulants as a coping strategy.

Our study suggests that students who choose coping responses that do not moderate the stressor, where possible, may cause themselves additional distress and avoid learning more effective coping responses. Helping students to understand stress and coping, and develop realistic stress appraisal techniques, may assist students in maintaining manageable distress levels and functioning both in and out of the university environment. Furthermore, assisting students who may be inclined to use prescription stimulants for cognitive enhancement may reduce possible drug-related harms.

AUTHOR CONTRIBUTIONS

CJ came up with the conceptual framework for the paper based on findings in a broader study. WH reviewed a draft abstract and approved the research idea. CJ carried out majority of data collection, analysis, and drafting of manuscript, with CF taking a smaller role in collecting data, analyzing data and writing the manuscript. BP helped CJ early on articulate the concept and provided significant early critique that shaped the paper. WH has provided expert knowledge, guidance, and revisions to the paper.

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"It Was Me on a Good Day": Exploring the Smart Drug Use Phenomenon in England

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The non-medical use of prescription medication for the pursuit of increasing cognitive and intellectual capacities (defined neuroenhancement) has received growing attention from the scientific community and policymakers alike. To date, limited qualitative data exist exploring the nature of the phenomenon, especially as a potentially emerging trend among university students in England. Existing American literature suggests that students believe that neuroenhancement helps the individual to maximize his/her time, consenting a suitable balance between work and leisure. Students' motivation to experiment with neuroenhancement appears to be more in line with a need to regulate emotions surrounding study/work settings than to actually improve cognitive abilities beyond normal levels. This study aimed to qualitatively explore representations, motivations, beliefs, and consumption styles of a cohort of university student users residing in England. Through snowball sampling, 13 informants were contacted and interviewed regarding their experience with neuroenhancers. Narrations were analyzed and interpreted using qualitative analysis software and Grounded Theory methodology. Participants belonged to a broad variety of university courses and were predominantly habitual consumers of modafinil. Neuroenhancers were acquired either through friends or via the Internet. Motivations regarded the need to "catch up" and be on par with high achieving students. The entire cohort had previously experimented with other psychotropic substances. Synthetic compounds in particular were believed to be "gateway" drugs to using neuroenhancers. Experimentation with neuroenhancement can be seen as a self-governing strategy aimed at achieving continued focused productivity. Participants acknowledged sustainable benefits in neuroenhancement as it optimized work performance. The majority of the cohort also contemplated the possibility of using these drugs in the future once they entered the workforce. Neuroenhancing drug users expressed "situated morality," differentiating between using these substances for assessments (exams) or during revisions, finding only the former as an immoral conduct. In the present scenario, it appears that neuroenhancement is practiced by small numbers of students. Nonetheless, the instrumental views of psychotropic substances held by many young adults and the globalization of these practices make the normalization of neuroenhancement a plausible possibility of the future.

Keywords: cognitive enhancing drugs, grounded theory, normalization, drug instrumentalization, students

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INTRODUCTION

Humanity has attempted to increase cognitive ability since very early in history. In ancient Greece, rosemary twigs were placed in scholars' hair with the hope to improve memory (Cakic, 2009). Traditional Chinese medicine has developed over thousands of years formulas reputed to improve cognitive abilities and concentration (Howes and Houghton, 2003). Today, the psychopharmaceuticalization of society (Goodman et al., 1996) has introduced prescription medications (modafinil, methylphenidate, phenethylamines, etc.) which can be used to increase cognitive performance in individuals suffering from mental health conditions such as narcolepsy, attention deficit disorders and shift work sleep disorder (Greely et al., 2008; Farah et al., 2014). Practices involving the non-medical use of such medications on the part of healthy individuals have been coined with the term pharmacological neuroenhancement, and have received growing attention on the part of the scientific community (Quednow, 2010; Repantis et al., 2010; Wolff and Brand, 2013).

In particular, an area of scientific interest resides in the use of these medications on the part of university students (Hall et al., 2005; Varga, 2012). Although it is still unclear if this trend is actually growing within the young adult population (Partridge et al., 2011; Ragan et al., 2013) or if it is a facet of a generalized aptitude on the part of western cultures to "medicalize" mental life (Coveney et al., 2012), ethical and policymaking issues still arise from this phenomenon. Besides whether neuroenhancement constitutes cheating (Lucke, 2012; Bell et al., 2013), it can also be hypothesized that these practices may become normalized, considering their appeal to younger adults entering the workforce (Wolff et al., 2014). If this population reputes these substances as instrumental to reach the full potential of their cognitive capacities, they may very well prolong neuroenhancement later in their life. Neuroenhancement already appears to be more or less prevalent in working populations (Maher, 2008; Banjo et al., 2010; Racine and Forlini, 2010; Wiegel et al., 2015). In a previous study, we found that socio-economic factors related to the competitiveness of the job market and preoccupations regarding occupational stability promoted a willingness to experiment with neuroenhancers (Vargo et al., 2014).

Neuroenhancement's actual efficacy in improving intellectual performance in healthy populations is yet to be established (Farah et al., 2014) and has not been proven safe (Maier and Schaub, 2015). The addiction risk posed by these drugs is still in debate but nonetheless, concerning side effects such as psychosis, insomnia, and irritability may arise from the use of these substances (Hysek et al., 2014).

Prevalence

According to survey data, significant portions (between 5 and 35%) of the North American student population utilize prescription medication to aid their cognitive abilities (Wilens et al., 2008). In the U. S., greater prevalence of use has been found among white male students, and members of fraternities and sororities (Hall et al., 2005; McCabe et al., 2005). Prevalence rates in Europe remain unclear, although they appear to be lower compared to North America (Maier and Schaub, 2015). In a study surveying UK students, less than 10% reported lifetime prevalence, but one third expressed an interest in experimenting with neuroenhancement (Singh et al., 2014). According to authors, low prevalence and high interest among British students could be moderated by the scarce availability of neuroenhancers (Singh et al., 2014).

It has also been debated that in the U. S., the endemic prescription of Ritalin to minors in the 1990s has contributed to the widespread use of prescription stimulants among young adults in higher education (Conrad and Potter, 2000; Loe, 2008). Although this interpretation is coherent within the North American context, it does not justify the apparent growing popularity of these practices in European contexts. Prescriptions to young children of these medications are less common in the UK, and have only risen in the last decade (Southall, 2007).

User Characteristics and Motives

Individuals who use neuroenhancers appear to have lower levels of self-efficacy and score higher on neuroticism scales (Maier and Schaub, 2015). They are also more likely to abuse other legal and illegal substances for self-medication (Novak et al., 2007; Singh et al., 2014). According to Quintero et al. (2006), the unprescribed use of medications for physical, social and psychological needs on the part of healthy young adults is part of broader normalization processes which involve the medicalization of a variety of states of being. College students view prescription drugs as a safer and more socially acceptable alternative to using "harder" drugs (Quintero et al., 2006; DeSantis and Hane, 2010). In this prospect, the self-medication hypothesis has been proposed by several authors as an explanation to these contemporary trends. Ford and Schroeder (2008) have found that students reporting higher levels of depression were more likely to experiment with prescription stimulants. Wolff and Brand (2013) found that university students view neuroenhancement as an acceptable means to cope with stress related to scholastic demands.

Qualitative research exploring neuroenhancement has evidenced that this practice is embedded in a multifaceted life characterized by high demands (Hildt et al., 2014). Students believe that neuroenhancement helps the individual maximize his/her time, thus consenting a suitable balance between work and leisure (Hildt et al., 2014). Moreover, Vrecko (2013) argues that students' motivation to experiment with neuroenhancement is more in line with the need to regulate emotions (increase enjoyment, interestedness, and drivenness) than to its actual capacity of increasing cognitive performance. According to de Souza (2015), biomedical discourses characteristic of contemporary society dominate students' beliefs in regards to the efficacy of neuroenhancement. The body-as-machine metaphor is used to interpret the problems of college life, and pharmaceutical drugs are viewed as a quick fix to the "mechanical" problems of lack of time, motivation and stress (de Souza, 2015). This cultural representation is amplified when exploring the views of students who have obtained prescriptions for neuroenhancers: the boundaries

between treatment and enhancement appear blurred, and prescription is used as a form of legitimization (Petersen et al., 2015a).

Aims and Objectives

Aims and objectives of the present study regarded the investigation of motivations, beliefs and attitudes tied to neuroenhancement on the part of university students, using qualitative and ethnographic techniques that give value to the individuals' subjective experience. England is characterized by different sociocultural factors than the North American context, thus it is relevant to provide a qualitative account of the neuroenhancement phenomenon within this context. In the UK, Ritalin (methylphenidate) is a Class B drug while modafinil is unclassified and more easily purchasable via the Internet (Advisory Council on the Misuse of Drugs [ACMD], 2015). Moreover, it is to be noted that the students participating in this study belong to the first wave of students who are paying full tuition fees as of September 2012 (£9,000 a year), which amount for increased pressure to do well in their studies to secure a good job upon graduation. It is to be noted that the present study does not aim to provide data representative of the entire population of neuroenhancement users, or of the subpopulation of University students in England using these types of enhancers. Moreover, our intent revolves around the need to explore psychosocial variables involving networks of users, outlining their specificities and identifying those elements attributable to a more generalized drug using culture.

Research Sample

For the purpose of this study, 13 informants were approached through ethnographic methodology, using snow-ball sampling (Fountain, 2000). The inclusion criterion was having used a neuroenhancer at least once without a medical prescription. Once key figures were contacted, these individuals were asked to help find more participants who belonged to the same social network of users.

Participants belonged to a small age range varying between 21 and 24 years old ($M = 22.5 \pm 0.9$ years). The sample contained more males ($n = 8$) than females ($n = 5$), reflecting survey results which evidence a propensity on the part of male students to experiment with these drugs (Hall et al., 2005; Vargo et al., 2014). The entire sample possessed a bachelor's degree and three participants were pursuing a postgraduate degree. Subject studied during undergraduate studies varied greatly, with four participants in the social sciences, four in computer and engineering and five in biology and medicine. Again reflecting survey results (McCabe et al., 2005), nine participants were white British, two were white Canadian and two were Pakistani. Within the sample, five participants had experimented with neuroenhancing drugs less than 10 times ("sporadic" users) while eight had used them habitually for a limited or extended period of time ("habitual" users). **Figure 1** depicts the sociogram of the study sample and the snow-ball sampling process.

MATERIALS AND METHODS

Qualitative research plays a fundamental role in the comprehension of the psychotropic drug use phenomenon (Fountain, 2000). Ethnographic research can provide qualitative information that not only contributes to a clearer understanding of new drug trends, but can also provide a term of comparison for quantitative research designs.

The methodologies utilized in this study are characterized by flexible data collection and an unstructured initial hypothesis. GT methodology and the Life-Story interview technique (Strauss and Corbin, 1990; Atkinson, 1998) permit the same themes proposed by the participants to become object of interpretation, maintaining the original linguistic code adopted by the sample. Through the Life-Story interview, participants are free to tell their own "story" in regards to neuroenhancement use. Subsequently, associations between thematic categories emerging from GT methodology determine the creation of a "single" storyline (Strauss and Corbin, 1990) which narrates the sample's experience and relationship with neuroenhancement. Coherently to a constructionist approach which interprets reality as resulting from a shared social construction (Kelly, 2003), it was chosen to interpret the research samples' narrations as "sense-making" of the investigated phenomenon. Considering the debates on the morality of neuroenhancement (Goodman, 2010) and that the non-medical use of some neuroenhancers (e.g., Ritalin) is illegal, it was acknowledged that participants would show resistance upon the request to share their personal experiences. Using a non-judgemental attitude and a tolerant approach, it was possible to overcome the suspicion and resistance that people would usually enact when prompted regarding their illicit conducts (Lambert, 1990).

Procedure

Participant recruitment followed the snowball sampling method. This technique assumes that the members of a social network are able to identify better than the researcher potential participants and are better informed in regards to the practices the researcher wishes to investigate (Lambert, 1990). Neuroenhancing substance users (participants 1, 2, 5, 8, and 13 in **Figure 1**) were initially identified (from previous studies and the researcher's social network) as key informants for the subsequent snow-ball sampling process. During data collection, the researcher took notes of the snow-balling process to aid the interpretation of results.

In agreement with the key informants, potential participants were contacted directly by the researcher and details regarding the study's objectives and procedure were first handedly described to them. Once the potential participant agreed to participate in the study, a meeting was arranged to carry out the interview. The setting of the interviews was a quiet and private area, where the interviewee could feel comfortable and at ease. As suggested by Atkinson (1998), participants were told before the actual interview to think about and try to recall significant events of the past and present which they found relevant to their experience with neuroenhancement. This would help the sense-making process and avoid that the interviewee presents a mere list

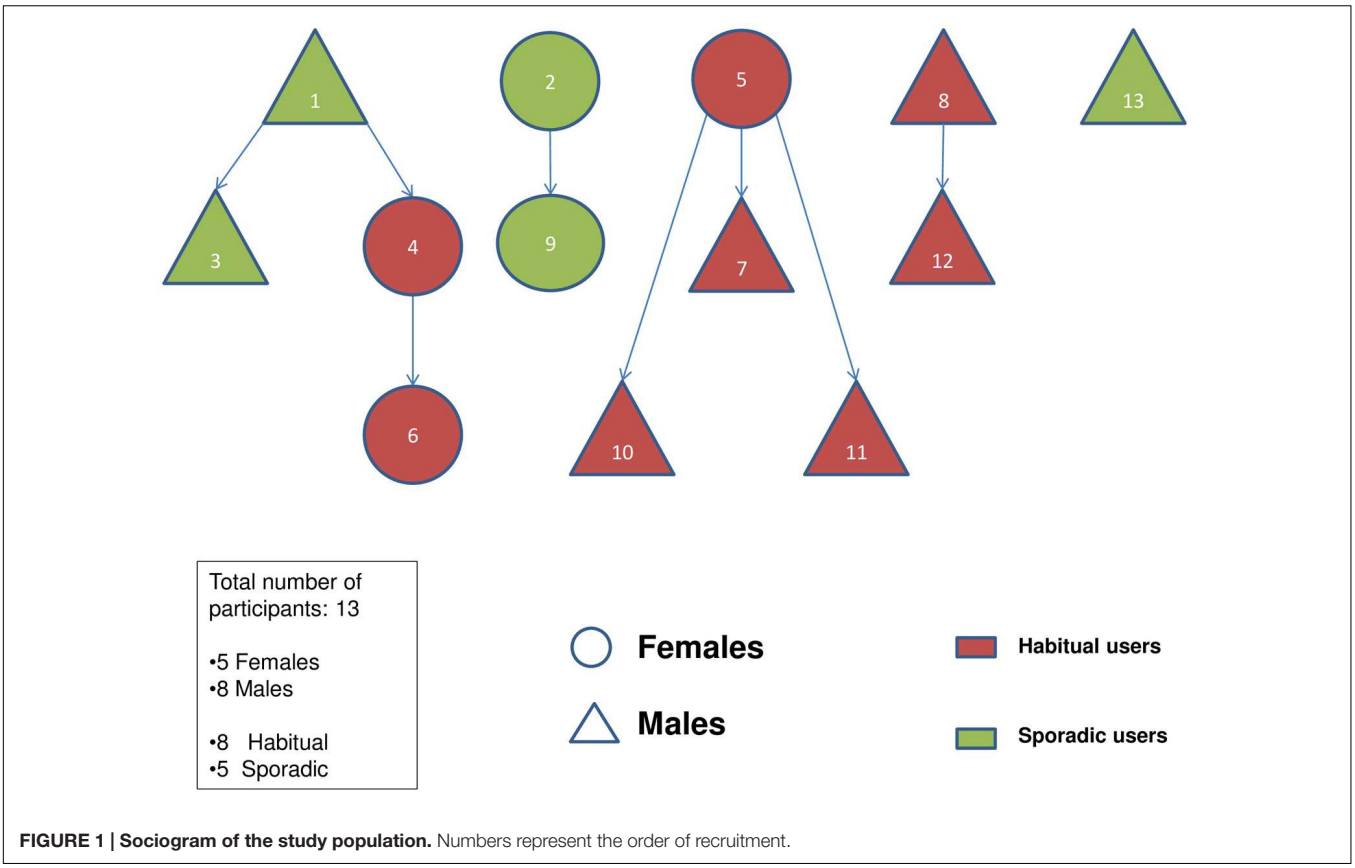

FIGURE 1 | Sociogram of the study population. Numbers represent the order of recruitment.

of events. The aim of this type of interview is in fact to achieve an actual *story* of the individual's experience, with characters, setting, plot, conflict, and resolution (Atkinson, 1998).

Interviews lasted approximately 45 min and were divided into three parts, each lasting about 15 min. According to Atkinson (1998), separating the phases of the interview helps the participant reflect and elaborate the contents he/she wishes to share. Each subpart was introduced by a prompt enquiring about the interviewee's relationship with neuroenhancement in the past, the present, and the future.

Interviews were carried out between March 2014 and March 2015. These were audio recorded and subsequently transcribed, omitting parts where the interviewee made reference to private information that could endanger their anonymity (names, places, etc.). The study was approved by the Kingston University Faculty of Science, Engineering and Computing Research Ethics Committee. At completion of the interview, participants were rewarded for their time and contribution with a £20 gift voucher.

The Life-Story Interview

The Life-Story interview (Atkinson, 1998), a discoursive and non-directed interview based on the active participation of the research sample in the creation of an interpretation, was chosen as our primary instrument for data collection. This interviewing technique views the narration of the *story* as the creation of a shared truth between the narrator and the listener. The story represents a privileged form of a unique personal expression, thus a way to access the cognitive world and representations of the storyteller.

The Life-Story interview is relatively unstructured and based on cooperation. The interviewer abstains from commenting or providing opinions in regards to the participant's conduct, and allows the interviewee to choose which topics and subjective experiences he/she wishes to share in relation to the interview's queries. In the case of the present study, three prompts were used to develop the interview:

(1) To describe the first time they experimented with neuroenhancement, their impressions, their beliefs before and after this event. To describe how the substance affected their body and their performance.
(2) The second prompt regarded the interviewee's relationship with neuroenhancers in the present: how did their use evolve from the first time they experimented with them and how the effect changed or maintained itself. The interviewee was then asked what opinions and attitudes their friends and family had in regards to neuroenhancement. In the case the interviewee was unaware of their friends' and family's attitudes, he/she was asked to imagine how they would react if they found out about their conduct.
(3) The third prompt asked the participant if he/she intended to use neuroenhancers in the future and under which circumstances. The interviewee was asked to imagine this hypothetical scenario, as well as what kind of motivations

would lead to this decision. The participant was then asked if he/she had ever used other psychotropic substances and how they were similar or different to the neuroenhancers they had experimented with.

These prompts aimed at collecting data regarding participants' attitudes, beliefs, and consumption trajectories in relation to neuroenhancement. In particular, the first question aimed at comparing beliefs regarding neuroenhancers before and after drug experimentation, and motivations tied to the intiation of this conduct. The second question aimed at collecting information regarding consumption trajectories, as well as participants' beliefs regarding ingroup and outgroups' attitudes and representations of psychotropic drug use. The third question explored intentionality of using neuroenhancement in the future and psychotropic drug use in general.

The life-story interview is a qualitative research method which does not aim at confirming the presence or absence of specific categories, but intends to collect an uncountable number of models and meanings that permit the formulation of inductive hypotheses. According to Atkinson (1998), historical truth is not the main issue when assessing a story's reliability. The possibility of considering the story worthy of trust is more relevant to the research process. The objective is not to measure an objective truth, but to collect information regarding the subjective experiences of a social event.

Grounded Theory Methodology

The goal of GT methodology is to systematically explore the meanings that the study participants attribute to the social reality they belong to, in order to produce "plausible interpretations" of a process or an interaction (Creswell, 2008). The main approach consists in a constant comparison between the different phases of interpretation, following a circular process (Strauss and Corbin, 1998). The starting point is a "cognitive query" regarding a specific issue, in our case the meanings attributed to neuroenhancement.

Through the *coding* process, the narrations are fragmented and reassembled via an abstraction process. Initially, concepts are organized in codes that are as close-fitting as possible to the text and progressively, the categorization process promotes the abstraction of these concepts. A code therefore, describes a portion of the text (quotation) through a label representing the narrative theme. Following the GT method, units are chosen according to their *groundedness* (prevalence in the narrations) or to their significance for the researcher's theoretical elaboration (Strauss and Corbin, 1990). The coding process is divided into three phases: open, axial, and selective coding. These do not follow a linear sequence but a circular one, as data and categories are constantly compared with each other in this process.

Data Analysis

This study utilized Atlas.ti software, which is tailor-made for GT methodology; and supports and organizes the coding procedure. Analysis of the relationships between codes is possible through the *query tool*, which analyses Boolean, logical, semantic, and proximal links between the categories. Atlas.ti also aids the analysis of relationships between conceptual categories and socio-demographic or other structural variables (i.e., gender, social network affiliation, drug used, and consumption style). Through this software program it is also possible to visually organize the codes emerging from the analytical process. **Figure 2** shows the conceptual map or *storyline* representing the organization of the codes. This organization is dictated by the GT methodology previously described, thus by the inductive–deductive process which aligns the researcher's interpretation to the co-occurrence and groundedness of the narrations' main themes.

RESULTS

The narrations of our study sample presented fairly coherent stories in regards to motivations, representations and effects experienced. As can be observed in **Figure 2**, reasons behind using neuroenhancers are semantically very similar (e.g., concentrate, stay awake, and focus). Regarding the type of neuroenhancers used, eight participants had tried modafinil (Modalert, Modavigil; a wakefulness promoting agent), two had also tried either Ritalin or Adderall, and three participants experimented with Adderall. Access to the prescription medications Ritalin and Adderall was determined by the fact that participants were in North America when experimentation with these substances occured, or someone who had these prescribed in North America provided them the drugs. According to the sample, prescription medications Ritalin and Adderall were very difficult to obtain in the UK whereas in North America, the use of these medications was very common among university students. No significant differences were found in regards to the effects provoked by these different compounds, thus the perceived effects were grouped for all three compounds.

The codification process resulted in the identification of 1593 quotations organized in 77 codes. The sample's storytelling was centered around explaining and justifying the reasons behind their prescription stimulants use to improve academic performance. The *storyline* elaborated from interpretation was organized according to this recurring and preponderant theme.

Motivations Leading to Neuroenhancement

The analysis of the sample's narrations evidenced that an important motivation leading to experimentation with neuroenhancers was work management and the possibility to intensify working sessions within limited periods of time. Primarily, participants hoped neuroenhancement would help them to "pull an all-nighter," boost their concentration, energy and motivation toward the task at hand. The need to resort to modafinil or other neuroenhancers derived from pressing deadlines or preoccupations with performing well.

> "*There are people who I was aware of, who were just working way harder than me and weren't taking any drugs at all. Maybe you're just bringing yourself up to their level by making the use of chemicals.*" Brian, aged 22.

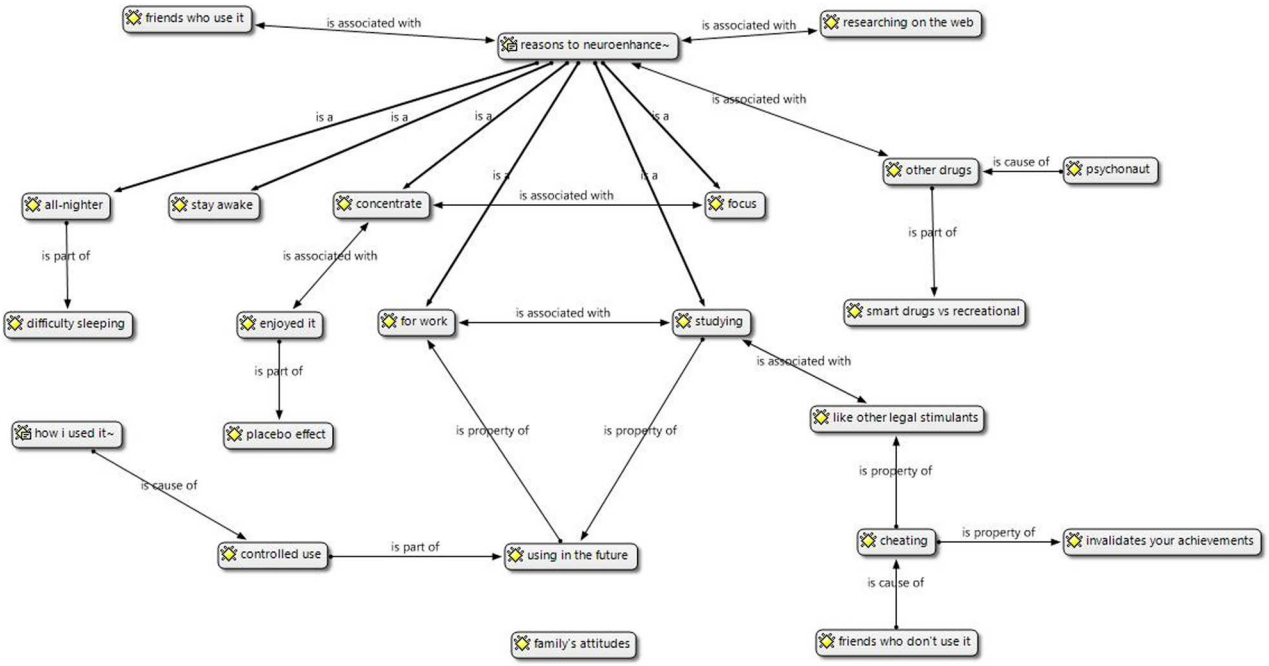

FIGURE 2 | Conceptual map depicting the sample's storyline. Nodes represent the most relevant codes according to groundedness and centrality in the interpretative process. Links represent relationships between codes.

As a matter of fact, many participants although aware of the existence of these compounds, chose to use them during the final year of their degree, when the pressure to outperform increased. These participants would also actively purchase modafinil from the Internet, driven by their need of assistance in their work management.

Expectations relative to neuroenhancers were mainly formed from the experiences of peers' already using these drugs or from the media. In general, participants would use Internet sites (e.g., Wikipedia, Reddit) to find more information on the effects of neuroenhancers and explore the experiences of other users. Moreover, these students were not preoccupied with negative outcomes and detrimental side effects: they viewed these substances as medications and had rarely heard of negative experiences on the part of their peers. Many students described not having particular expectations in regards to cognitive enhancement and described their motivation to try as determined by situational needs.

> *"I didn't really think much of it, I just took it to see if it would really work."* Caroline, aged 21.

Moreover, a small number of participants were motivated to try neuronhancement out of curiosity, as they belonged to social networks of individuals who were using these drugs. Reassured by their peers' positive experiences and motivated by the growing popularity of "smart drugs," these participants usually experimented sporadically and never acquired the substance directly.

> *"To be honest, the first time I tried it, it was more because I was bored of revising and writing the essays, rather than the fact that I necessarily needed to focus more. I thought 'maybe it will be easier, maybe it'll be more interesting, and I'll see what it's like'. I got it because he was getting some anyway, so he just got me some to try."* Brenda, aged 24.

Before experimenting with neuroenhancement, the entire sample had tried at least one illicit substance. The most commonly mentioned drug was cannabis, then MD/MA (or ecstasy). Other illicit substances mentioned were cocaine, speed (or base), MDA, hallucinogenic mushrooms, LSD, ketamine, 2C-B, 2C-I, 2C-E, and 25I. For some, MD/MA was considered a "gateway" drug to neuroenhancement: their initial experience with this drug led them to change their views in regards to synthetic compounds. After experimenting with them, participants saw synthetic drugs as less dangerous, thus contemplated the possibility of using them for purposes different from entertainment. Moreover, other participants considered themselves "drug effect explorers" or, as defined by the drug using community, *psychonauts*: this term defines individuals who see psychotropic substances as a means to explore new experiences and new ways of relating to their environment. Drugs can be used rationally to enhance one's life experiences and are considered privileged keys to access different levels of consciousness.

Experimentation with Neuroenhancement

The majority of participants had a positive experience with neuroenhancing drugs. Actual effects met their expectations and

the substance assisted them in meeting their goals. In line with their expectations, participants felt more awake and focused, "*on the ball*" and more interested in their work. Interestingly, many acknowledged the possibility of experiencing a "placebo effect." Although it was recognized that neuroenhancers did not actually change the way participants thought or that they actually "created" motivation, effectively concentrating and focusing on their tasks provided them with a sense of enjoyment. In this sense, it can be stated that neuroenhancement provides an experience that in general, is rewarding for the user both at a cognitive as at an affective level. As would be expected, participants who described the experience as pleasurable, tended to intensify and habitually use neuroenhancers.

> *"It was me on a good day, it wasn't any better than me on a good day, it was me on the best day I could ever have."* Amber, aged 22.

> "*I don't even know why, because I know I could do without them, it kind of makes me feel more confident. If they're there, I know I could have a good day of work if I needed to but I could do without it.*" Mohammed, aged 22.

In general, participants described a primary effect that would last 5–8 h, and a feeling of being awake that would prolong itself for several more hours. The outcomes of neuroenhancement were reputed similar to those felt when drinking coffee, although participants recognized distinct differences in the capacity to remain focused and concentrated. Effects depended on the dosage taken, and many participants experimented with different amounts to achieve the desired effect. Taking half a pill for example, provided alertness while taking a full pill would provide more noticeable effects, both physically and psychologically. In particular, a full pill would give a "buzz," a heart rush and a significant change in their motivational drive. Some participants described the "rush" as similar to that experienced from MD/MA or cocaine but to a lighter extent.

Consumption patterns varied widely, with some participants taking just a quarter of a pill sporadically to others who would take several pills during a single session. Intense use, such as using the substance for several days in a row, was described as extremely tiring for the body, and some believed that this conduct led to habituation. The majority of participants would take a half or full pill in the morning to take advantage of the effect during the day. Some would take a pill in the evening to work throughout the night. This modality usually resulted in a negative experience, as it affected sleeping patterns. Moreover, the majority of participants would use neuroenhancing substances for study revisions or to complete coursework (writing essays, project assignments). Often other stimulants were used simultaneously, such as coffee or caffeine pills, and energy drinks. Some, in particular males, had experimented with these substances in different contexts than solitary studying, and had neuroenhanced at work, for job interviews, during work out sessions, when clubbing or during examinations.

> "*And then I also took half before I went for an exam. To be honest that was one of the best effects I had out of it... I think it definitely improved my memory in that case.*" Toby, aged 22.

In general, participants did not complain of particular side effects although the most frequently mentioned was insomnia. This side effect mainly concerned those using modafinil. When experiencing unwelcomed side-effects, participants adjusted their consumption style in order to avoid this side effect, or utilized other psychotropic substances (cannabis) to relieve their difficulty sleeping. A minority of the sample complained that using the drug when living a state of stressfulness would worsen the feeling and provoke panic and excessive worrying. Again, participants reported that they adjusted their consumption pattern in order to control this side effect.

Distractions from work would also provoke a state of uneasiness and distress. Some participants described being annoyed by distractions and avoiding social interactions. This feeling though depended on the intentionality of the user, as participants who were using neuroenhancers in work contexts contrarily described enjoying social interactions as they improved their communication style and eloquence. Participants described having a "craving" or "fixating" on doing something when under the effect of neuroenhancers, and for this reason keeping focused on the task at hand was important. This feeling would manifest itself in chain smoking, reordering objects or intense "Internet surfing." Regarding physical side effects, some participants described having heart palpitations at the initial stages, loss of appetite and increase in thirst.

A duality emerged from the narrations in regards to the addictive quality of neuroenhancers. On one side, participants were informed that these substances were not physically addictive, and this was seen as a reassuring characteristic. On the other, some participants were preoccupied with psychological dependence, as they considered the possibility after continued use, of having to rely on these substances to carry out their work in an effective manner.

> "*Thinking about what I've said it sounds like I'm addicted to them or something. The language that's being used, I want to take it once a week, adding it to your daily life sounds quite similar to someone addicted to a specific drug, like coke, I'd only take it during the week ends. That's how it starts, and then you're taking it all the time.*" Paul, aged 24.

Participants viewed neuroenhancement as very different from using other psychotropic substances. The effects of illicit substances were seen as more intense and involving the whole body. Neuroenhancement on the other hand was perceived as more "psychological," and not as physiologically overwhelming. Neuroenhancing drugs did not manifest any noticeable physical effects, whereas other drugs were much more visible. Many participants underlined the fact that neuroenhancers did not provoke particular negative effects once they wore off, contrarily to other drugs such as cocaine or MD/MA which are characterized by a "come down." Moreover, neuroenhancement was seen as significantly different from other illicit drugs as the former were used for functional reasons and not recreationally.

Attitudes of Participants' Social Networks

Participants described belonging to social networks where the majority of peers did not use neuroenhancers. On the other hand, the three participants who had also experimented with neuroenhancement in North America described a different scenario where these substances were widely used. The cohort believed that non-users were better organized, more focused and therefore did not need to use neuroenhancers for their studies. According to participants, people who did not use neuroenhancers made this decision based on moral grounds, as they were against using drugs in general. Many participants shared that some of their peers and friends were curious about their experience with these substances. They believed that given the opportunity, more students would experiment with neuroenhancers.

> "*Friends opinions usually start off negative just because they say you don't know what it is, you go online. Until you don't explain to them or you show them, then they're like 'Oh my god, I want to try some.' When they learn about it, their opinion seems to change.*" Claire, aged 21.

The sample expressed concerns in regards to general attitudes which believed neuroenhancement was a form of cheating. Participants were worried that their choice might invalidate their achievements or that they would be kicked out of university or fired if they were exposed. In particular, habitual users discussed more of this topic, yet believed that this moral approach was inappropriate. Neuroenhancement was said to be the same as drinking coffee during studying sessions and did not change an individual's capabilities. Some believed that using neuroenhancers during exams would be a form of cheating; using them during revisions was not unethical.

> "*It's kind of giving you an unfair advantage but then at the same time there are people who I was aware of, who were just working way harder than me and weren't taking any drugs at all.*" John, aged 23.

Participants stressed that in comparison to individuals who were more capable at focusing and managing their commitments, they were not gaining an unfair advantage but were contrarily "catching up." When considering peers who were as stressed or as under pressure as them, participants saw that neuroenhancement was providing them an unfair advantage. Nonetheless, the fact that these substances were widely known and easily purchasable on the Internet provided a justification to their conduct.

With very few exceptions who felt that their caregivers completely trusted their judgment and decisions, the sample believed that family members would disapprove of their experimentation with neuroenhancers. In general, family members were believed to have negative attitudes toward drugs, and neuroenhancers would be seen as belonging to the same category. The sample believed their family saw drugs as dangerous and taking drugs to study would be perceived as "crazy." They would usually not discuss these experiences with their parents or siblings, as they were preoccupied with raising concerns.

Intentionality to Use Neuroenhancement in the Future

The study sample believed that overall, neuroenhancement had a positive impact on their work commitments. In particular, it helped them stay awake and complete their work in restrained periods of time. Nonetheless, they believed that it did not "add" anything to their actual capabilities, and some were convinced that having better management skills would have provided the same contribution as neuroenhancement.

> "*If I was getting behind work and I felt like I needed to catch up, if I felt I needed to get a lot of work done in a short period of time, there was a deadline moving, or if people around me start taking them I might feel maybe I should take them as well.*" Peter, aged 22.

With the exception of two participants, the whole cohort contemplated the possibility of using neuroenhancers in the future. The reasons behind this intentionality were the effectiveness of these substances and their affordable price. The possibility of using neuroenhancers was considered situation dependent, as participants believed that neuroenhancement was useful in times of intense stress and responsibilities. Some participants still possessed a "stash" of these drugs in case of need. As can be seen in **Figure 2**, participants viewed the possibility of neuroenhancing again as associated to their postgraduate studies or to a future job characterized by tight deadlines and individual projects. The possibility of being fired or getting in trouble in a work environment due to this practice was considered a deterrent from further experimentation.

> "*There's a big difference between taking it at university and taking it at work because work is the rest of your life, and having to take drugs to get through the rest of your life sounds terrible.*" Brian, aged 23.

Moreover, the fear of "losing control" over one's drug using was considered another deterrent to further experimentation. Participants also contemplated the possibility of using other neuroenhancing drugs. According to their narrations, many other neuroenhancing drugs are available via the Internet and web forums provide valuable information on their efficacy. An example of alternative neuroenhancing methods is "stacking," implying the use of cocktails of substances to reach optimal levels of alertness and concentration.

DISCUSSION

The study sample's motivations to neuroenhance resided in their need to "catch up" and cope with their work related demands, in line with previous qualitative literature on the phenomenon (Repantis et al., 2010; Coveney, 2011; Vrecko, 2013). These findings also appear to be aligned with quantitative studies showing a propensity on the part of lower achieving students to use neuroenhancement (Benson et al., 2015).

Neuroenhancement was usually a solitary practice integrated with the way participants preferred to study. Modafinil was the most widely used neuroenhancer, as it was easily purchasable via the Internet and posed no legal consequences. In line with

Singh et al.'s (2014) results, prescription medications Ritalin and Adderall appeared to be more difficult to obtain within the UK. The study's participants who had tried these medications accessed them through individuals in their social network that had prescriptions (which were usually obtained in North America).

The decision to experiment with neuroenhancing drugs was also determined by their apparent growing popularity and by the attention they receive on Internet forums and the media. Participants believed these substances were safe, being medications. Moreover, their peers' experiences with these drugs were generally positive, leading to a willingness on the part of some participants to try these substances without any specific need to "enhance." In our sample, willingness to purchase modafinil via the Internet was associated with habitual use and intentionality to use neuroenhancers in the future.

Previous experiences with various psychotropic drugs led to a propensity to further experiment with neuroenhancement, confirming findings from previous literature (Novak et al., 2007). In particular, participants had broadly experimented with several synthetic substances which they conceived as a "gateway" to using other synthetic compounds for work related purposes. This representation confirms the idea that psychotropic drugs are integrated in western cultures, and seen as instrumental for the adaptation to modern life (Müller and Schumann, 2011). Moreover, the sample often practiced polysubstance use by simultaneously ingesting neuroenhancers with other legal stimulants to heighten their effect. Other psychotropic drugs such as cannabis were used by some participants to relieve the side effects caused by modafinil use. The instrumental view of psychoactive substances is further evidenced by the "psychonautical" culture (where drug experimentation is part of existential investigation) emerging from the sample's narrations. This theme originating from the psychedelic subcultures of the 1960's now appears to be a cultural value characterizing contemporary youth cultures (Schifano et al., 2003; O'Brien et al., 2015).

The sample's experience with neuroenhancement led them to believe that these substances couldn't actually change their cognitive and intellectual capacities, yet the majority continued their use and found them to be useful for their work performance. Although potential users believe prescription stimulants can improve cognitive abilities, research has shown little evidence of significant improvement in healthy populations. On the contrary, it is suggested that neuroenhancers may have a greater impact on mood and perceived motivation (Ilieva and Farah, 2013). Differently from legal stimulants such as coffee or energy drinks, neuroenhancers not only promoted wakefulness but the possibility "*to not worry about anything except for the task at hand*." According to the narrations, their efficacy resided in helping them achieve a sense of focused productivity which fulfilled their motivational goals, consequently providing for the majority a sense of enjoyment. In this sense, neuroenhancers are not strictly viewed as a means to push the boundaries of what is possible for the individual but as a way to normalize performance during abnormal circumstances (Coveney, 2011).

Participants were aware of side effects consequential to neuroenhancement use and abuse. They demonstrated to be "rational" drug users by adopting strategies to control their use patterns and regulate consumption (Zinberg, 1984). These varied from reducing the amount of substance ingested to adjusting their times of consumption in order to avoid insomnia, which was the most frequent side effect mentioned by the sample. Moreover, the majority of participants viewed the use of neuroenhancement as circumstantial to specific moments of their existence (i.e., during periods of intense stress). Nonetheless, a dichotomy emerged from the narrations regarding the addictiveness of neuroenhancers. On one hand, these were not considered to be addictive, and this constituted a reassurance regarding their safety. On the other, some participants had experience of peers' abuse and reliance on these substances, thus acknowledged the possibility of becoming "psychologically" addicted. Prevention and harm reduction strategies should address this ambiguity and better inform public knowledge regarding the meaning and psychological harm of addiction in its various forms (Ross et al., 2010). Moreover, research has demonstrated that students who neuroenhance adopt at-risk conducts which could lead to addiction (Hildt et al., 2015).

Another concern arising from the sample's narrations regarded the morality of their conduct. Participants did not entirely believe that neuroenhancement constituted cheating, especially when carried out for revision or coursework completion. Using neuroenhancement for an exam or job interview on the other hand was reputed cheating. It appears that this conduct is practiced following a contextualized or situated morality. Similar to previous findings (Vargo et al., 2014), zero-sum situations elicit moral disagreement regardless of enhancement utilized. The need to enhance is a response to contextual demands linked to ecological pressures, evidencing its functional role in the daily routines of users. Attitudes of the general population toward neuroenhancement were perceived as negative. Participants believed that if their conduct were exposed, they would be fired or their achievements would be invalidated. Due to the fear of society's negative judgement, participants held conflicting norms in relation to using medications for competitive needs, similarly to what has been found in athlete populations in relation to doping (Bloodworth and McNamee, 2010). Considering what has been learned from drug prohibition and anti-doping (Kayser and Smith, 2008), repression inevitably leads to a submersion of the phenomenon and consequently to increased difficulties when public health would aim at addressing the issue. Under a harm reductionist perspective, it would be important to not address this phenomenon using moralistic and purely bioethical paradigms (Ketchum, 2013), as these approaches produce social deviance and further harms, especially when neuroenhancing compounds are used for self-medication (Quintero and Nichter, 2011; Levinson and McKinney, 2013).

Beliefs regarding the effectiveness of neuroenhancing drugs led the majority of participants to imagine using these substances in the future. In this study, attitudes of non-users toward neuroenhancement appear to be negative. If the functionality of these drugs for users' lives and goals emerge in other quantitative and qualitative studies in different contexts, a normalization

of this conduct in future years can be hypothesized (Benanti, 2010). Our cohort resided in England but those who had also experienced with these drugs in North America described distinct differences in regards to the availability and popularity of neuroenhancement drugs. When also considering the notable attention these practices receive from the media (Partridge et al., 2011), a process of cultural accommodation and globalization of these practices is possible in the years to come.

Neuroenhancement seems to be an adaptation to work-hard play-hard lifestyles, as well as to the competitiveness of contemporary higher education. Borrowing from Foucault's (1985) concepts relative to the *Technologies of the Self*, drug use conducts have an adaptive and functional role within the environmental setting in which they are carried out. Prescription stimulants can be seen as a strategy to govern the self, not just in relation to quantifiable results, such as grades or amount of work done, but also in relation to the affective experience of working hard and feeling on par with high achievers. Considering the evidence available and the absence of studies outside controlled laboratory experiments objectively verifying the efficacy of cognitive enhancers for healthy populations, it is difficult to confidently state in a quantifiable and objective manner that users are or are not actually enhancing their cognitive performance. Participants' narrations nonetheless speak of advantages in terms of fulfilled accomplishments and focused productivity, and not in terms of quantifiable differences in their learning abilities. Although neuroenhancement drug users hold representations of cognitive enhancers as drugs capable of enhancing cognitive and intellectual abilities, they appear to be motivated to use these substances to keep up with academic demands, and not to push the limits of their abilities (i.e., being smarter or knowing more). Thus, their use is tied to the need to comply with and readjust their work performance to meet the day-to-day demands of their academic courses. Neuroenhancement can be seen as fulfilling efficacies both at a social as at a cultural level (Petersen et al., 2015b).

Outlining an articulate description of the phenomenon which considers the complexity of social attitudes, motivations, beliefs, and consumption styles seems coherent with the real-world applications of the findings of this study. Nonetheless, limitations reside in the small sample size and in the absence of quantitative information regarding personality and intra-individual variables. A limitation that can be identified in the methodology used in this study regards the risk of not fully satisfying theoretical saturation through the recruitment process. The snowball sampling process was in fact interrupted as participants were not able to identify more users and it was not possible to expand the study's cohort. However, in qualitative research sufficiency of sample size is measured by depth of data rather than frequencies (O'Reilly and Parker, 2012). The high coherence identified in the participants' narrations reassures that the data are reliable and relevant to understanding academic neuroenhancement in the English context. It can be hypothesized that the hidden population of neuroenhancing drug users is very contained in the geographic area assessed, and this may have been reflected in the snow-ball sampling process.

Moreover, a re-analysis of the narrations could involve more than one researcher in the coding process. Further investigation of this phenomenon could explore and compare the representations of young adults using neuroenhancement in work related contexts, or in different geographical settings. Future research should also investigate the neuro-biological effects neuroenhancing compounds produce on healthy individuals (Ilieva and Farah, 2013) as well as how perceived effectiveness and intrinsic motivation influence initiation and patterns of use (Ilieva and Farah, 2015).

CONCLUSION

Our intent was to provide theoretical hypotheses that could contribute to the understanding of the phenomenon and promote effective preventive strategies. The sample used neuroenhancing substances to satisfy adaptive needs related to their work and academic demands. Substances were acquired from unsafe sources and many participants showed a willingness to resort to these compounds if they encountered stressful work situations in the future. These aspects should be taken into consideration in future harm reduction interventions. Understanding how an individual belonging to a specific social category constructs the usefulness of a psychotropic substance, and comprehending which motivations and beliefs lead him to experiment with it, are vital for the elaboration of appropriate and effective harm prevention.

AUTHOR CONTRIBUTIONS

EV designed the study and wrote the protocol with AP. EV performed the literature search, developed the interview protocol, carried out recruitment, collected the data, transcribed the interviews, analyzed the interviews, and drafted the first version of the manuscript. AP contributed to writing the manuscript. All authors contributed to and have approved the final manuscript.

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The Complexity of Neuroenhancement and the Adoption of a Social Cognitive Perspective

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This contribution attempts to provide a broad perspective to the psychological study of neuroenhancement (NE). It departs from the assumption that, as the use of performance enhancing substances in sport, the use of substances with the aim of improving one's cognitive, motivational and affective functioning in academic domains is a goal-directed behavior. As such, its scientific study may very well benefit from an analysis taking into account the psychological processes regulating people's behavioral intentions and decisions. Within this broad framework, this contribution addresses several issues that currently seem to characterize the debate in the literature on neuroenhancement substances (NES) use. The first conceptual issue seeks to determine and define the "boundaries" of the phenomenon. The second issue concerns the empirical evidence on the prevalence of using certain substances for the purpose of NE. Finally, there is a debate around the ethical and moral implications of NE. Along these lines, the existing psychological research on NE has adopted mainly sociological and economic decision-making perspectives, greatly contributing to the psychological discourse about the phenomenon of NE. However, we argue that the existing psychological literature does not offer a common, explicit and integrated theoretical framework. Borrowing from the framework of doping research, we recommend the adoption of a social cognitive model for pursuing a systematic analysis of the psychological processes that dynamically regulate students' use of NES over time.

Keywords: neuroenhancement, students, social cognitive models, doping, substance use

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PREMISES

The use of pharmacological substances to enhance performance is an issue psychologists have thoroughly investigated in the sport context. In this context, a broad psychological perspective focusing on the social-cognitive processes regulating one's intentions and use of performance enhancement substances has been largely adopted by many scholars in recent years (see Ntoumanis et al., 2014, for a review). Similarly, the use of substances with the aim of improving one's cognitive, motivational and affective functioning in academic and work contexts has also recently emerged and been debated as a critical research issue in the literature on neuroenhancement (NE) and cognitive enhancement (e.g., Zohny, 2015).

We believe this debate is currently focusing on three clearly distinct—and yet intimately related—issues. There is a conceptual focus which seeks to determine and define the "boundaries" of the phenomenon. Some boundaries stress the distinction between pharmacological and non-pharmacological substances to enhance performance. Other boundaries instead refer to the distinction between "hot" (e.g., mood, motivation) and "cold" (e.g., attention, memory) cognitions, and to the general notion that cognitive enhancement seemingly only matters for the latter type of cognitions (Zohny, 2015). Finally, there are boundaries stressing the contexts in which it is plausible or relevant to discuss NE (e.g., work places, educational settings) and those to which the term of NE instead does not apply (e.g., recreational settings, sport settings). There also is an empirical debate seeking to clarify the prevalence and social relevance of using certain substances for the purpose of NE (e.g., Maier and Schaub, 2015). There is also a debate around the ethical and moral implications of NE, with the literature primarily addressing issues ranging from personal safety, to the social responsibility of institutions, agencies or firms promoting or contributing to NE, to issues about a person's character and his or her right to seek a good life (Schermer, 2008). This contribution briefly summarizes the key elements of these debates and, while recognizing the undisputable value these debates have for scientific progress, also argues that they are undermined by a lack of explicit reference to a clear theoretically-grounded psychological perspective. We believe that the adoption of a theoretical psychological perspective, as in the case of existing doping research, would favor a shift from insightful and yet seemingly endless debates to prospective research and intervention programs that could clarify and possibly resolve some of these debates. In the remaining sections of this paper, we attempt to sustain and justify this core belief.

Finally, it is important to note that the present contribution unfolds with an exclusive focus on academic or educational contexts. Typically, these contexts offer clear-cut and broadly acknowledged behavioral criteria and protocols for referring to and observing individuals' performances. Furthermore, as also suggested by Kipke (2013), academic examinations and testing might warrant special attention, as performance outcomes clearly rely on one's cognitive functioning and capacities. Third, NE in these settings also raises issues regarding the integrity and validity of academic examinations and testing results. As a concluding note, academic and educational settings are also the contexts which have often been the target of empirical studies on NE (e.g., Smith and Farah, 2011; Franke et al., 2014).

DEFINITIONAL AND CONCEPTUAL ISSUES CONCERNING NEUROENHANCEMENT

Should NE be considered a complex property of some substances currently is a matter of debate, and the scientific evidence and general understanding of this proposition seems far from having been ascertained or confirmed (Zohny, 2015). Even if one departed from the definition of NE that in recent years has been shared by scholars and referred to as "*. . . the misuse of prescription drugs, other illicit drugs, or alcohol for the purpose of enhancing cognition, mood, or prosocial behavior in academic or work related contexts*" (e.g., Maier and Schaub, 2015, p. 156), we feel that this definition, despite being extremely clear, still needs further consideration or clarification.

First, some NE studies distinguish among prescribed-substances (e.g., Methylphenidate, Modafinil, Amphetamines, etc), substances of abuse (e.g., Alcohol, Cannabis, Cocaine) and over-the-counter substances or drugs (e.g., caffeinated products and food supplements), the so called "soft enhancers" or "life style" drugs (e.g., Franke et al., 2014; Maier and Schaub, 2015). Second, clarification seems warranted when one considers the extent to which NE must or needs to be conceived with respect to behavioral rather than cognitive performance criteria (e.g., a substance enhances one's memory which, in turn, affects and positively contributes to one's exam grades). With this in mind, some scholars (e.g., Zohny, 2015) distinguish substances' effects on mood or motivational processes from their effects on other processes, such as attention or memory, and go on in suggesting that the latter type of effects specifically constitutes cognitive enhancement. Whether "cognitive" only refers to what is traditionally seen as "cold" cognition or, rather, whether motivational and emotional processes legitimately represent parts of one's cognitions, is an issue that has been long debated in classical work (e.g., Pessoa, 2008).

In the context of the present contribution, it seems important to us to highlight another issue that perhaps has relevant assonances with the distinction between "cold" and "hot" cognitions. One's use of cognitive enhancement substances legitimately may call upon two broadly alternative cases. The first envisions the possibility that one may use a given substance to improve his or her "*effort*" as a means of performance (e.g., Ritalin to stay awake and study for a longer time). The second envisions the possibility that one may use a given substance to improve specific cognitive functions or tasks (e.g., memory recall or problem solving). Both cases highlight a critical issue in any psychological analysis, that of one's goals for choosing a particular course of action. At any rate, to what extent any or both of these cases must be considered "cognitive enhancement" has not yet been addressed by the existing literature. At a minimum, however, it seems plausible to hypothesize that users of cognitive enhancement substances might primarily be interested in achieving their best (academic) performance outcomes, rather than in the processes underlying any particular outcome.

We think the above issues, despite their peculiarities, offer some ground for consensus. The use of neuroenhancement substances (NES), by students or professionals, reflects a person's conscious or deliberate intentions, at least in the case of unsupervised use of psychoactive substances by healthy individuals. Furthermore, no matter what the NES chemical and medical properties are with respect to the enhancement of specific cognitive capacities (e.g., memory), we think that there is consensus in the literature on the general view that individuals pursue enhancement goals with the intention of influencing actual behavioral performance.

THE PREVALENCE OF NEUROENHANCEMENT SUBSTANCE USE

A large number of recent empirical NE studies have estimated the prevalence of NES use. However, it seems difficult to draw a precise and reliable map of its diffusion, as prevalence estimates often vary widely depending upon sampling criteria, measurements, and demographic or contextual factors. For instance, Smith and Farah (2011), in reviewing 28 epidemiological studies on the prevalence of non-medical prescription drug use in American and Canadian students, reported a lifetime use of stimulants for non-medical purposes ranging from 5.3 to 55%. More recently, Franke et al. (2014) have reviewed studies reporting prevalence rates for NES use that range from 1 to 20%.

The issue of reliably assessing prevalence rates has also characterized doping research, and the distinction between legal and illegal substances has definitely contributed to establishing valid estimates of doping use in sport settings (Mallia et al., 2013). In a similar fashion, it is plausible that the distinction among non-medical prescription drugs, drugs of abuse, and soft-enhancers (e.g., caffeine) in the NE literature might contribute to a correct assessment of prevalence estimates.

Generally speaking, however, the estimation of prevalence of NES use, as for performance enhancing substances (PES) use in sport, remains a complex process and many methodological issues could influence it and lead to increasing variability and differences in findings across studies. For instance, while social desirability biases might easily come into play in the assessment of doping substance use in the face of explicit sport law regulations against their adoption, the lack of any clear-cut social or legal norms about NES may pose complex challenges for correct or agreed-upon prevalence rates.

ETHICAL AND MORAL ISSUES CONCERNING NEUROENHANCEMENT

There is an important debate concerning the ethical issue related to the use of NES. Some scholars argue that, especially in the context of examinations, this behavior might be considered cheating, because its use may alter performance (Schermer, 2008), as in the well-known case of doping in sports. There are a number of parallels between the misuse of NES in academic settings and doping in sport. In both contexts, an individual is misusing a substance that has legitimate medical value with the purpose of increasing one's own performance. As in the field of doping research (see, for istance, Petroczi, 2013), several scholars have debated the ethical and moral implications of using NES in academic or educational settings (e.g., Kipke, 2013; Zohny, 2015).

At the same time, there are also some clear differences between the use of NES and the use of doping substances. In sport contexts, there is a clear and well-accepted distinction between which substances and protocols are illicit (illegal performance enhancing substances) and which are not (legal performance enhancing substances). In educational and academic contexts, at least until recently, law or binding regulations concerning the use of cognitive enhancing substances were lacking. Some universities, in fact, have recently clarified in their own academic conduct policies that the use of prescription medications aimed at enhancing academic performance falls in the category of "academic dishonesty" (e.g., Duke University: Policy on academic dishonesty; URL: https://studentaffairs.duke.edu/conduct/z-policies/academic-dishonesty), even though policies of this sort are still a matter of debate (e.g., Schermer, 2008; Dubljević, 2013). Interestingly, Dodge et al. (2012) have separately assessed how individuals judge others who use performance enhancing drugs both in athletic and academic domains. Not surprisingly, their findings suggest that people tend to consider the use of NES to enhance academic performance as more acceptable than doping substance use in sport.

One could reasonably argue that the lack of clear-cut norms and regulations for the use of NES makes the latter unfit for being treated as a case of cheating. Nonetheless, there are some actions or behaviors that, despite not being clear violations of explicit rules or norms, allow one to gain some advantages over others and, as such, might be considered unfair. In the sport context, these behaviors fall under the rubric of "gamesmanship" (e.g., Lee et al., 2007). According to Vallerand et al. (1996), in order to approach the ethical evaluations of a given behavior, one needs to recognize the social origins of these evaluations, that is, the notion that they emerge over time by consensus within a social context. How individuals perceive the misuse of substances has important implications for prevention efforts. Thus, the use of NES might be evaluated positively when the emphasis and judgment criteria focus on one's effort to perform well, and negatively when the emphasis and judgment criteria focus on one's attempt to increase one's own academic performance through the help of pharmacological aids, thus altering the integrity and validity of (his or her) academic examinations and testing results.

Faulmuller et al. (2013) emphasize that the indirect psychological costs of the use of NES is related to the ways people attribute performance to agents. Given that people tend to exaggerate the efficacy of cognitive enhancers, they might perceive NES users' performance as not fully attributable to them. At any rate, individuals contemplating the use of NES may very well dwell upon the moral implications of using these substances and utilize their personal self-sanctions as internal deterrents. These possibilities imply and presuppose a strong link between NES use and moral reasoning, and this link is consistent with a well-grounded psychological literature addressing the relations between moral reasoning and the use of performance enhancing substances in sport-related contexts (e.g., Lucidi et al., 2008, 2013; Zelli et al., 2010).

A SOCIAL COGNITIVE PERSPECTIVE ON NEUROENHANCEMENT

The Theoretical Framework: Its General Principles and Hypotheses

From the previous sections of this contribution, it appears clear to us that the use of NES falls under the rubric of a goal-directed behavior and, as such, its scientific study may very well benefit from a psychological analysis presuming that NES use depends on self-regulation and on the mental processes intervening in behavioral intentions and decisions bounded to specific social

contexts or situations. So stated, our view endorses key tenets of a social cognitive perspective on NES use, insofar the latter "*. . .. entails not only behavioral skill in self-managing environmental contingencies, but also the knowledge and the sense of personal agency to enact this skill in relevant contexts. Self-regulation refers to self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals. . ..*" (Zimmerman, 2000, pp. 13–14).

These general notions seem to be shared at least in part by psychological research that has adopted sociological and economic decision-making perspectives (see Sattler et al., 2014, for a thorough review). Much of this research (e.g., Müller and Schumann, 2011; Sattler and Wiegel, 2013; Wolff and Brand, 2013) broadly argues that the use of (or willingness to use) cognitive enhancement substances reflects an instrumental decision individuals make on the basis of the degree to which substance use "fits" their personal preferences, perceived opportunities and constraints. Consistent with this general hypothesis, empirical studies have focused on several classes of variables, ranging from considerations about the risks and benefits of particular cognitive enhancement drugs' characteristics (e.g., Castaldi et al., 2012), to forms of social environmental effects (e.g., forms of social control, social pressure from significant others) influencing decisions about the use of enhancement substances (e.g., Glannon, 2008; Bavarian et al., 2013) to, finally, personal characteristics (e.g., cognitive test anxiety, lack of academic competencies) that may make individuals more vulnerable at the time of deciding whether to use cognitive enhancement substances (e.g., Tice and Baumeister, 1997; Klassen et al., 2008; Weyandt et al., 2009).

The focus on instrumental decisions also seems to characterize other NE research stressing the need for psychological theorizing (e.g., Wolff and Brand, 2013; Wolff et al., 2014). This research hypothesizes that NE is "*. . .the medically unsupervised use of presumably psychoactive substances by healthy individuals who expect this substance to be a functional means of enhancing their cognitive capacity. . .*" (Wolff et al., 2014, p. 2). This research very recently has moved on and utilized principles and constructs borrowed from occupational theories (e.g., demands, strain, burnout) to address the "means-to-end" NE hypothesis in educational settings (Wolff et al., 2014). This research has shown that the use of lifestyle drugs and prescribed NE drugs is more likely among university students who experience burnout, and that the use of NES worsens students' psychological experience of academic demands and interferes with their motivational resources. These existing contributions have greatly contributed to the psychological discourse about NE.

This notwithstanding, it seems difficult to identify in this literature a common and explicit theoretical framework. On the contrary, and interestingly, doping-related psychological research has in recent years been able to adopt a broad social cognitive view that clearly and systematically put the study of performance enhancement substances on a qualitatively different level of theoretical analysis. According to this social cognitive view, doping substance use is a goal-directed behavior that is the expression of one's intentional processes, and these intentions reflect the influence of socially construed belief systems. Illustratively, this broad view has found clear and distinct expressions in research that variously adopted either a "theory of planned behavior" approach (e.g., Lucidi et al., 2004; Lazuras et al., 2010; Mallia et al., 2013), a motivational orientation approach (e.g., Barkoukis et al., 2013) or an explicit social-cognitive integrative approach (e.g., Lucidi et al., 2008, 2013; Zelli et al., 2010; Lazuras et al., 2015). All these cases typically refer to belief structures, and these beliefs may specifically refer to either outcome beliefs guiding one's behavioral attitudes about doping use, behavioral control beliefs concerning the means for reaching one's own goals, personal and self-regulatory efficacy beliefs, or moral disengagement beliefs that one may adopt to counteract personal self-sanctions against doping use (e.g., Lucidi et al., 2008, 2013; Lazuras, 2015).

This belief-based social cognitive doping research has more recently been integrated by an additional social cognitive component, namely, one's self-relevance appraisals of interpersonal and social situations eliciting doping use (Zelli et al., 2010, 2015). Theoretically, over time, this component would interact with belief systems in increasing the probability that people would show doping intentions and actual doping use.

We argue that the theoretical and empirical advances of doping research stand as a mature and plausible model for moving forward on NE research. In the following section, we describe, albeit in broad terms, some key elements of a possible social cognitive research program for the study of NE use.

A Social Cognitive Research Program for Neuroenhancement

As an initial note, we believe that a social-cognitive model of NES use might nicely integrate some of the theoretical propositions that seem to have variously characterized recent NES studies. One proposition calls upon an incremental-functional view of NES use, and the hypothesis that students might be motivated and involved in performance enhancing practices that, over time, increasingly acquire high instrumental value (e.g., Sattler and Wiegel, 2013; Wolff and Brand, 2013). Another proposition calls upon belief systems which may build upon a link between one's performance enhancement goals and the functional or moral implications of NES use as a purposive, goal-driven behavior.

We also believe that, at least in educational settings, research attention to constructs such as (a) students' attitudes about NES, (b) prospective intentions toward NES use, (c) efficacy and self-regulatory beliefs about one's own capacity to counteract social and internal pressures to use NES, (d) personal standards and justifications in favor or against NES use, and (e) students' appraisals of the self-relevance of interpersonal situations eliciting NES use would have high scientific value. It would acknowledge and be consistent with the above theoretical propositions, as these social cognitive constructs recognize and encompass the dynamic and functional properties of one's life and behavioral experiences with NES that existing literature has highlighted. More importantly, it would provide a single, unified, framework for theory development and assessment, allowing scholars to pursue a systematic analysis of the psychological processes that dynamically regulate students' use of NES over time.

In our view, such a novel research focus should rely on and pursue some key research objectives. The first is concerned with the possibility of clearly establishing the empirical relations between people's behavioral intentions and actual NES use. This first objective necessarily calls upon a second objective, namely, the adoption of longitudinal research designs allowing scholars to establish how behavioral intentions contribute to *changes* in NES use over time (i.e., controlling for behavioral stability). The third objective is concerned with the possibility of identifying the set of key social-cognitive variables regulating people's NES behavioral intentions. As these variables operate in a system of dynamic relations, the empirical focus cannot merely address their unique contribution to behavioral NES intentions. Rather, it also needs to address how changes in the model of effects on behavioral intentions correspond to changes in the interrelations among key social cognitive variables and in their unique contributions. Consistent with a social-cognitive view of NES, the hypothesis of a system of interrelated variables influencing one's behavioral intentions also calls upon the empirical possibility that this system is dynamically linked to the meaning people assign to relevant social and interpersonal situations possibly soliciting NES use. We believe this is a fourth critical objective for NES research, insofar as one's intention to use NES might be strengthened or, alternatively, weakened by the degree to which social and interpersonal situations acquire personal relevance.

As a concluding note, we firmly believe that the social cognitive research perspective that has been briefly outlined above can provide, whatever its findings might be, the specific contours for any educational program that is interested in effectively addressing NES use and its implications in people's daily lives and experiences.

AUTHOR CONTRIBUTIONS

AZ, FL, and LM substantially have equally contributed to the development and preparation of the manuscript. Furthermore, all authors have approved the final version of the manuscript. Finally, the authors have agreed to be accountable for all aspects of the manuscript in ensuring that questions related to the accuracy or integrity of any part of it are appropriately investigated and resolved.

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Cerebral Correlates of Automatic Associations Towards Performance Enhancing Substances

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The direct assessment of explicit attitudes toward performance enhancing substances, for example Neuroenhancement or doping in sports, can be affected by social desirability biases and cheating attempts. According to Dual Process Theories of cognition, indirect measures like the Implicit Association Test (IAT) measure automatic associations toward a topic (as opposed to explicit attitudes measured by self-report measures). Such automatic associations are thought to occur rapidly and to evade voluntary control. However, whether or not such indirect tests actually reflect automatic associations is difficult to validate. Electroencephalography (EEG) has a superior time resolution which can differentiate between highly automatic compared to more elaborate processing stages. We therefore used EEG to examine on which processing stages cortical differences between negative or positive attitudes to doping occur, and whether or not these differences can be related to BIAT scores. We tested 42 university students (31 females, 24.43 ± 3.17 years old), who were requested to complete a brief doping IAT (BIAT) on attitudes toward doping. Cerebral activity during doping BIAT completion was assessed using high-density EEG. Behaviorally, participants D-scores exhibited negative attitudes toward doping, represented by faster reaction times in the doping + dislike pairing task. Event-related potentials (ERPs) revealed earliest effects between 200 and 300 ms. Here, a relatively larger occipital positivity was found for the doping + dislike pairing task. Further, in the LPP time range between 400 and 600 ms a larger late positive potential was found for the doping + dislike pairing task over central regions. These LPP amplitude differences were successfully predicting participants' BIAT D-scores. Results indicate that event-related potentials differentiate between positive and negative doping attitudes at stages of mid-latency. However, it seems that IAT scores can be predicted only by the later occurring LPP. Our study is the first to investigate the cerebral correlates that contribute to test scores obtained in the indirect testing of automatic associations toward doping. The implications of our results for the broader NE concept are discussed in light of the conceptual similarity of doping and NE.

Keywords: EEG/ERP, anti-doping, attitudes, Implicit Association Test (IAT), indirect tests, substance abuse, Neuroenhancement (NE)

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INTRODUCTION

Studies frequently find that considerable proportions of university students (Maier et al., 2013; Mazanov et al., 2013; Dietz et al., 2013a; Wolff et al., 2014), high-school students (McCabe et al., 2012) and traditional employees (Maher, 2008) use different types of substances to enhance their academic or work performance. This behavior has been labeled Neuroenhancement (NE; Wolff and Brand, 2013; Wolff et al., 2014). As NE is a relatively new research topic it has been suggested to draw upon knowledge from the conceptually similar, but theoretically and empirically much further developed field of doping research (Wolff and Brand, 2013). Semantically and conceptually, the similarity of both behaviors has been implied already (e.g., Maher, 2008; Dodge et al., 2012; Dietz et al., 2013b). The means-end relation represented by both behaviors is comparable. For example, erythropoietin (EPO) can be used in sports as a means to enhance athletic endurance (Lasne and de Ceaurriz, 2000). Among university students, Ritalin can be used as a means to enhance concentration (Forlini and Racine, 2009). Thus, both substances are used as means toward the end of performance enhancement. Social science research on doping is already much more evolved compared to research on NE and there already exists a wealth of knowledge on psychological processes that play a role in doping behavior (for a recent Meta-Analysis, see Ntoumanis et al., 2014). Among the best predictors of doping behavior are doping attitudes (Mallia et al., 2013; Ntoumanis et al., 2014). For the assessment of doping attitudes one needs to consider two different *types* of attitudes as explicated by Dual Process Theories of Cognition (Brand et al., 2015).

Dual Process Theories of Cognition

Dual-Process Theories of Cognition (e.g., Evans and Stanovich, 2013) postulate two different processes of thinking, resulting in two different types of attitudes (e.g., Gawronski and Bodenhausen, 2006). In the Associative-Propositional Evaluation Model (APE) Gawronski and Bodenhausen specify the features of associative (*implicit*) and propositional (*explicit*) attitudes: Associative processing is characterized by automatic affective reactions. This means that when presented with a doping stimulus, an athletes' affective association with doping is automatically activated ("doping is good"). This association does not have a truth value (i.e., it does not matter whether or not said athlete actually deems said association appropriate or inappropriate; for a doping specific overview please see Brand et al., 2015) and must not necessarily correspond to the results of propositional reasoning that characterizes explicit attitudes. Propositional reasoning is based on syllogistic inferences ("Doping is necessary to win") that hence have truth values, meaning that they reflect a persons' reasoned evaluation toward a certain topic. There is ample evidence that shows that these different types of attitudes differentially affect behavior (e.g., Hofmann et al., 2005, 2007).

Dual Processes in Doping Research

Most research on social-cognitive predictors of doping so far has focused on the more traditional explicit attitudes (e.g., Ntoumanis et al., 2014). However, recent years have seen an increased focus on implicit doping attitudes (e.g., Petróczi et al., 2011; Brand et al., 2014b; Wolff et al., 2015). There are strong theoretical claims that the use of performance enhancing substances is not an entirely reflective process (e.g., Brand et al., 2015). Another reason is a measurement issue: Depending on what type of attitude one wants to assess, the ideal methods of assessment differ (e.g., Brand et al., 2015). Implicit attitudes are mostly assessed via indirect reaction-time based tests, whereas explicit attitudes are assessed using direct tests (i.e., self-report measures). However, direct tests are prone to response distortion when socially sensitive topics are addressed (Tourangeau and Yan, 2007). The social desirability of doping has been shown to influence self-reported doping attitudes (Gucciardi et al., 2010). Methods for the indirect assessment of automatic attitudes are reportedly much more robust toward such deliberate response bias problems (Wolff et al., 2015).

Indirect Attitude Measurement

Implicit Association Tests (IAT; Greenwald et al., 1998) are computerized reaction-time based tests. Most generally, participants are asked to categorize two concepts (one target and one evaluative) as fast as possible with the same response key on the computer's keyboard. The speed of categorization varies as a function of the semantic association of these concepts. Closely associated concepts (e.g., flowers + like) are categorized faster than disjunct concepts (e.g., insects + like). One of the IAT's most important features from a measurement perspective is its postulated potential to control for the social desirability bias by evading voluntary control and being rather robust toward deception attempts compared to direct tests (Kämpfe et al., 2009). Indeed, compared with questionnaires, IATs display higher predictive validity when socially sensitive constructs are measured (Greenwald et al., 2009). Recently, a shorter and comparably valid and reliable IAT variant has been introduced: The Brief IAT (BIAT) (Sriram and Greenwald, 2009). The doping BIAT investigated here has been found to be a valid predictor for positive biochemical doping test results (Brand et al., 2014b).

EEG Measuring Automaticity

In sum, for the assessment of socially sensitive topics (like doping or NE) indirect measures seem to be more suitable than direct measures (e.g., Wolff et al., 2015). However, such evidence does not allow for conclusions as to whether or not IAT scores actually reflect automatic associations toward the target concept. This is crucial if one wants to understand the actual cognitive processes that are reflected in the doping BIAT score. One way to test if doping BIAT scores reflect automatic associations is electroencephalography: Electroencephalography has a superior time resolution which can determine differential processing of doping attitudes in terms of milliseconds. The use of event-related potentials (ERPs) allows to investigate such differential processing on highly automatic or more deliberate processing stages and to relate these differences to actual BIAT performance. In general components are divided into ones with early (e.g., N1) middle (P2) and long latencies (LPP), where earlier components are thought to reflect more automatic processing. The N1 is

thought to be a marker of visual discrimination of stimuli (Vogel and Luck, 2000) and more sensitive to physical stimulus properties (Olofsson et al., 2008). But even the N1 can be modulated by emotional content (Pourtois et al., 2004) or task context (Schindler et al., 2014). Further, the N1 component as well as the following P2 component are influenced by visual attention (Hillyard et al., 1998; Luck et al., 2000; Codispoti et al., 2006). On the other hand, the late positive potential (LPP) is thought to be a marker of elaborate evaluation of the stimulus and is connected to memory encoding (Dolcos and Cabeza, 2002; Schupp et al., 2007).

ERP Studies on the IAT

So far, a few studies have investigated event-related potentials of IAT completion (He et al., 2009; Hurtado et al., 2009; Ibáñez et al., 2010; O'Toole and Barnes-Holmes, 2010; Williams and Themanson, 2011). However, considerable variability of the used stimuli, investigated samples and analysis approaches makes these findings difficult to generalize. For example, Ibáñez et al. (2010) investigated early components, while Hurtado et al. (2009) analyzed the later occurring amplitudes. In both papers attitudes of indigenous and non-indigenous participants toward both groups were investigated. Results showed a stronger processing of the *incongruent* condition for indigenous participants (in this case, non-indigenous + like) at the early N170 and partially at the LPP. On the other hand, more frequently larger LPP amplitudes are reported for the *congruent* condition (He et al., 2009; O'Toole and Barnes-Holmes, 2010; Williams and Themanson, 2011). Williams and Themanson (2011) for example found no early effects, but found a larger LPP for straight couples paired with positive stimuli compared to gay couples and positive stimuli (Williams and Themanson, 2011). The authors reasoned that this might reflect the emotional congruency between the target concept and the evaluative concepts (i.e., positive/like). Further, regarding the relationship between ERP differences and IAT scores, amplitude differences in the LPP time window seem to be more consistently correlated with IAT scores (He et al., 2009; Hurtado et al., 2009; Williams and Themanson, 2011), while for early components, correlations are either not reported (Ibáñez et al., 2010), or found to be insignificant (He et al., 2009).

Hypotheses

Taken together, some ERP studies show IAT differences already at early processing stages while late effects are reported more consistently. At these later stages a larger LPP can be expected for the congruent condition (in our case doping and dislike). Further, these later differences seem to be related to IAT scores.

We aim to further investigate the mechanisms involved in completing a BIAT on performance enhancing substances. To this aim, a large sample of participants performed a brief BIAT while high-density EEG was recorded. We investigated if doping attitudes measured by a validated doping BIAT are differentially processed on early and middle perceptual (N1, P2), or at late processing stages (LPP). The empirical findings of early perceptual differences during an IAT are inconsistent. Thus, investigations of the occipital N1 and P2 component are exploratory. However, we expected to find LPP differences, more precisely, a larger LPP for negative doping attitudes. Finally, we tested the hypothesis that differences at the LPP would be related to IAT D-scores.

METHODS

Participants

Forty-eight students were recruited at the University of Bielefeld. They gave written informed consent and received course credit for participation. For a high-density EEG study, this is a rather large sample, enabled by data collection in two consecutive studies which investigated effects of different faking strategies on the doping BIAT (Schindler et al., 2015b; Wolff et al., in prep.). Specifically, in these studies baseline BIAT scores were compared to subsequently faked BIAT scores. These studies did not investigate content or congruency effects of these baseline scores and were not aimed at investigating how a non-faked BIAT score is associated with electrophysiological markers. The study was conducted in accordance to the Declaration of Helsinki and was approved by the ethics review board at the University of Bielefeld. One participant was excluded due to a history of previous mental disorder, another due to a previous brain tumor, and six participants due to excessive artifacts, leaving 42 participants for final analysis. One participant was left-handed.

These 42 participants (31 females) were 24.43 years old on average ($SD = 3.17$, $Min = 20$, $Max = 30$). Screenings with the German version of the Beck Depression Inventory and the State Trait Anxiety Inventory (Spielberger et al., 1999; Beck et al., 2001) revealed neither clinically relevant depression ($M = 4.25$, $SD = 3.46$) nor anxiety scores ($M = 30.00$; $SD = 3.60$).

BIAT Completion

We used a validated picture-based doping BIAT (Brand et al., 2014a). In this BIAT, the combined task consists of the combined classification of the target categories *doping* vs. *health food* with the attribute categories *like* vs. *dislike*. Since *doping* is the focal concept in this BIAT (i.e., the concept of interest), *doping* is mapped on the same response key (in our case the "I" key on the keyboard) throughout the whole test and only the attributes are changed across blocks (Sriram and Greenwald, 2009). In block A, *doping* and the attribute *like* share the same response key. In block B, *doping* and *dislike* share the response key "I." Before each block the stimulus pairings that have to be categorized with the "I" key are shown on an introductory screen to allow participants to familiarize themselves with the stimulus material (*doping* + *like* in block A, *doping* + *dislike* in block B). The category labels that are relevant for the respective block (*doping* + *like*, or *doping* + *dislike*) remain on the top and bottom of the screen throughout the categorization task, to ensure that participants are aware what stimuli are focal in the current block. The *doping* concept was represented by pictures of pills, ampoules, and syringes; the *health food* concept by apples, cereal, and vegetables; the *like* attribute by positive emoticons; and the *dislike* attribute by negative emoticons.

EEG Recording

Participants were seated in a dimly lit and sound attenuated room. Continuous EEG signals were recorded from 128 BioSemi active electrodes (www.biosemi.com) with a sampling rate of 2048 Hz. During recording, Cz was used as a reference electrode. Biosemi uses two separate electrodes as ground electrodes: First, a Common Mode Sense active electrode (CMS), and second, a Driven Right Leg passive electrode (DLR). All electrodes were placed according to the 10–20 system using an elastic head cap. Four additional electrodes (EOG) measured horizontal and vertical eye movement. These were placed at the outer canthi of the eyes and below the eyes.

EEG data was pre-processed using Brain Electrical Source Analysis package (BESA; www.besa.de). Offline, data was re-referenced to the average reference. To identify and correct eye-movement artifacts the automatic correction algorithm implemented in BESA was used (Ille et al., 2002). EEG data was filtered using a 0.1 Hz (6db/oct) forward filter and a 40 Hz (24db/oct) zero-phase filter. Filtered data were segmented from 100 ms before stimulus onset until 1000 ms after stimulus presentation. One hundred millisecond before stimulus onset was used for baseline correction. Automatic artifact detection implemented in BESA was used to eliminate remaining artifacts defined as trials exceeding a threshold of 120 μV. In the doping + like block 13.04% and in the doping + dislike block 14.58% of the trials were rejected as artifacts, with no differences between the blocks [$t_{(41)} = 0.95$, $p = 0.35$]. For both conditions about 34 trials were included for averaging.

BIAT Analyses

Behavioral data was analyzed with JASP (www.jasp-stats.org/, Love et al., 2015). Paired *t*-test were set-up to investigate differences in raw-reaction times as well as effects for the resulting *D*-scores between both blocks. *D*-scores are already a standardized aggregate measure of reaction time differences between the doping + like and the doping + dislike block. Effect sizes for repeated measures were calculated for all statistical tests (Cohen, 1988). Finally, parametric Pearson correlations were calculated between BIAT D-scores and mean microvolt amplitude differences of ERP components.

EEG Data Analyses

EEG data were analyzed with EMEGS (http://www.emegs.org/, Peyk et al., 2011). For statistical analyses, paired *t*-tests were set-up to investigate differences between both blocks (block: doping + like vs. doping + dislike) in time windows and electrode clusters of interest. Effect sizes were calculated for all statistical tests (Cohen, 1988).

We investigated congruency effects on the N1, P2 and LPP components (see also Williams and Themanson, 2011). These ERP components were quantified post-stimulus for the occipital N1 from 150 to 200 ms and for the occipital P2 from 200 to 300 ms. Fronto-centrally, the LPP was identified from 400 to 600 ms. For the occipital sensor cluster 20 electrodes were investigated (PO7, PO9h, PO9, PO3, POO3, O1, OI1, I1, POOz, Oz, OIz, Iz, POO4, O2, OI2, I2, PO6, PO8, PO10h, and PO10) and over fronto-central locations a cluster of eighteen electrodes was used (FC1, FCz, FC2, FCC1, FCC1h, FCCz, FCC2h, FCC2, C3h, C1, C1h, Cz, C2h, C2, C4h, CCP1h, CCPz, and CCP2h).

RESULTS

Behavioral Results

Mean reaction times for the doping + dislike block ($M = 688$ ms, $SD = 118$ ms) were significantly faster than for the doping + like block [$M = 790$ ms, $SD = 286$ ms; $t_{(41)} = 2.37$, $p < 0.05$, $d = 0.47$]. Participants' average doping attitudes as measured by their D-Score in the BIAT displayed a significantly negative affect toward doping [$M = -0.24$, $SD = 0.52$; $t_{(41)} = 3.00$, $p < 0.01$, $d = 0.94$].

EEG Results

Occipital Sensor Cluster: N1 (150–200 ms) and P2 (200–300 ms)

For the occipital N1 (150–200 ms), no significant differences were observed [$t_{(41)} = 1.27$, $p = 0.21$, $d = 0.07$]. At the occipital P2, significantly larger amplitudes were observed for the doping + dislike condition [$t_{(41)} = 2.55$, $p < 0.05$, $d = 0.13$; see **Figure 1**].

Fronto-central Sensor Cluster: LPP (400–600 ms)

Over the central sensor cluster, in the time window of the Late Positive Potential a main effect of condition was found. Here, the doping + dislike block was found to elicited a significantly larger LPP compared to the doping + like block [$t_{(41)} = 2.80$, $p < 0.01$, $d = 0.23$; see **Figure 2**].

Relationship between ERPs and BIAT D-scores

For the occipital sensor cluster, no significant relationship between amplitude differences and BIAT D-scores were observed regarding the N1 or the P2. While significant differences in the processing could be observed on the occipital P2, these differences could not be related to the behavioral differences ($N = 42$, $r = 0.18$, $p = 0.26$). However, at the late processing stages of the LPP, amplitude differences were significantly correlated with BIAT D-scores ($N = 42$, $r = -0.43$, $p < 0.01$; see **Figure 3**). Here, with increasing anti-doping D-scores, the LPP amplitude differences became larger.

DISCUSSION

This study investigated the cerebral processing of negative and positive attitudes toward performance enhancing substances measured by a doping BIAT. As expected, the doping BIAT scores in our sample of university students reflected a negative attitude toward doping. Specifically, they were faster when doping and dislike shared the same response key and slower when doping and like shared the same response key. This resulted in a significant negative D-score. Further, neuroscientifically we found differences on middle and late ERP components: An enhanced occipital P2 as well as a larger LPP for negative doping attitudes.

We expected to find differences at late processing stages, namely an enlarged LPP for the congruent condition (i.e., the

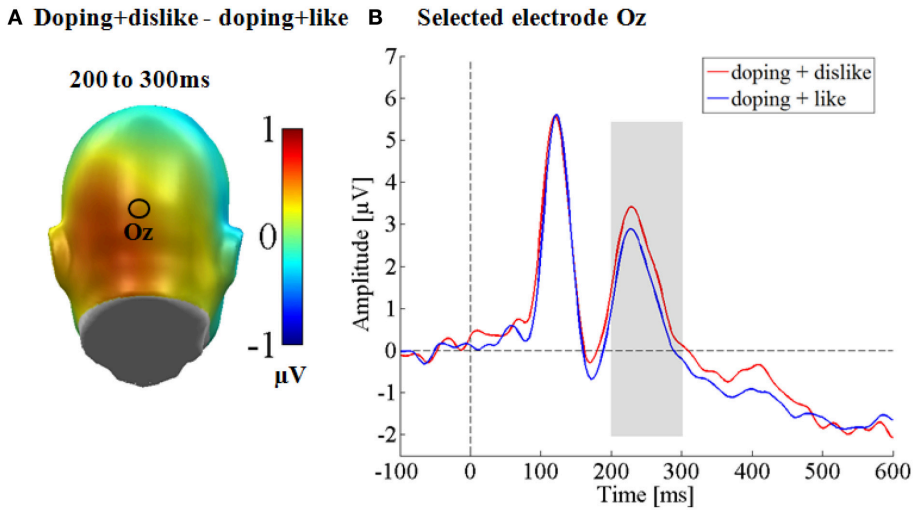

FIGURE 1 | Occipital effects on the N1 and P2 components. (A) Difference topographies for negative doping affect minus positive doping affect **(B)** selected electrode Oz for the occipital electrode set, displaying the time course over occipital sites.

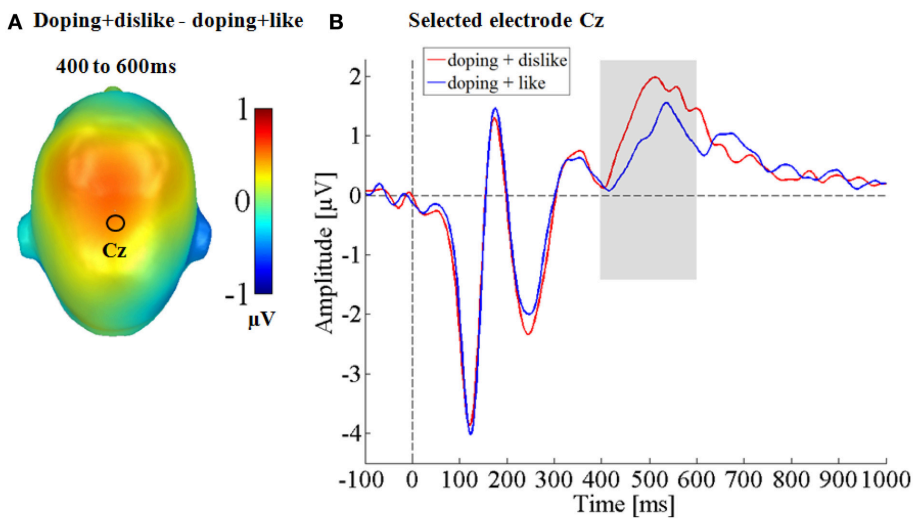

FIGURE 2 | Central effect on the LPP component. (A) Difference topographies for negative doping affect minus positive doping affect **(B)** selected electrode Cz for the central electrode cluster, displaying the time course over central sites.

doping + dislike block), based on previous ERP reports (He et al., 2009; Hurtado et al., 2009; O'Toole and Barnes-Holmes, 2010; Williams and Themanson, 2011). Indeed, by examining attitudes toward performance enhancing substances we could observe a larger LPP for the congruent condition. Further, the larger LPP for negative doping attitudes was also linked to the BIAT D-score. Larger LPP effects for negative doping attitudes were found to co-occur with stronger anti-doping D-scores.

Larger LPPs have been previously found for emotional congruent target stimuli (Dillon et al., 2006; Spreckelmeyer et al., 2006). Thus, the larger LPP for the congruent IAT condition has been interpreted to reflect a form of emotional congruency (Williams and Themanson, 2011).

Typically, larger LPPs are also found for emotional compared to neutral pictures (Schupp et al., 2004b, 2007), interpreted in terms of facilitated attention toward these emotional stimuli (Cuthbert et al., 2000; Schupp et al., 2004a) due to their higher relevance for reproduction and survival (Lang et al., 1997). In this experiment the pictures and emoticons were the same in both conditions. However, research has demonstrated that the LPP can be modulated by giving instructions about stimulus interpretation (Hajcak and Nieuwenhuis, 2006; Foti and Hajcak, 2008). In the same vein, context effects have been shown to change ERPs toward physically identical stimuli in

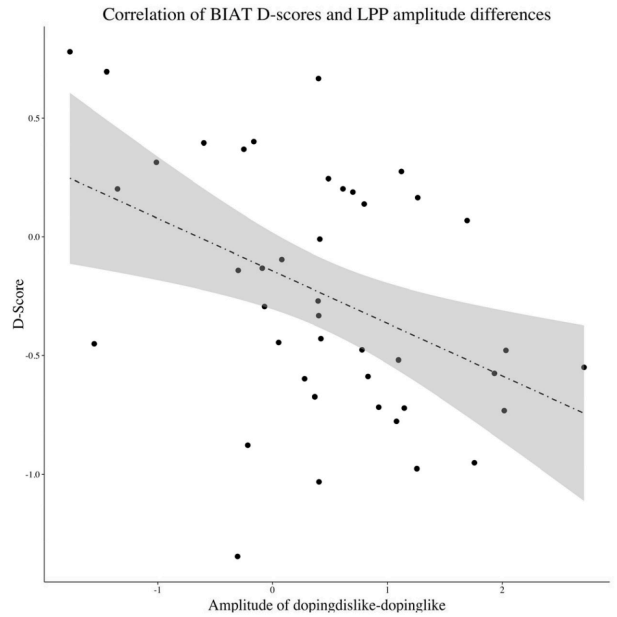

FIGURE 3 | Significant correlation ($r = -0.43$, $p \leq 0.01$) between LPP amplitude differences and BIAT D-Scores. The shaded area represents the standard error for each conditional mean as predicted by the dotted regression line.

various paradigms (Bublatzky and Schupp, 2012; Fields and Kuperberg, 2012; Wieser and Keil, 2013; Schindler et al., 2014, 2015a; Klein et al., 2015). Here, larger LPP amplitudes typically occurred in the more salient context, e.g., in the condition were participants expect a threat of shock (Bublatzky and Schupp, 2012), which is more self-relevant (Fields and Kuperberg, 2012), emotionally more engaging (Klein et al., 2015) or socially more intense (Wieser and Keil, 2013; Schindler et al., 2015a). Similarly to explicit instruction-dependent LPP modulations (Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006), participants might implicitly perceived the doping and dislike combination to be emotionally more arousing or salient.

Further, regarding the early differences between both conditions we found a larger occipital P2 for negative doping attitudes. There is evidence that in visual paradigms the parieto-occipital P2 originates from extrastriate visual cortex (Mehta et al., 2000). Regarding its functional meaning, it has been found that the P2 is influenced by visual attention, where larger P2 components are observed for attended stimuli (Luck et al., 2000). Further, the P2 can be a predictor for subsequent visual detection success (Mathewson et al., 2009), where larger P2 components during fixation cross presentation were found for trials which were later detected compared to trials which were missed (Mathewson et al., 2009). It is unclear why these early differences emerged when responding to perceptually identical stimuli. It might be that participants were more engaged in the doping and dislike task and paid more attention to the stimuli. However, these findings need to be replicated, as early effects are not consistently found in ERP studies on the IAT (Williams and Themanson, 2011).

Still, the P2 differences were not linked to the BIAT D-score. It might be that these earlier differences reflect an early attention enhancement by the emotional congruency, preparing the participants to react faster. Considering re-entrant processing explanations (Pourtois et al., 2013), signaling from the amygdala regarding the emotional salience might have preceded task related signaling (as reported from intracranial recordings, see Pourtois et al., 2010). Eventually, the actual BIAT scores seem to be uniquely predicted by the later occurring LPP.

These results point to deliberate involvement in performing the doping BIAT. However, this does not imply that participants can easily choose how to respond to an IAT. First, the doping BIAT has been found to predict biochemical doping test results (Brand et al., 2014b). Further, when incentivized to fake doping attitudes, it has been found that participants were successfully changing their self-reported doping attitudes but not their BIAT scores (Wolff et al., 2015). It is thus concluded that IATs are less controllable and still more implicit than many other tests (De Houwer et al., 2009). It could be that although participants may be in general able to alter responses they are unwilling to change their IAT performance (e.g., they may be afraid to get caught or too exhausted to think about a successful strategy). This could also explain mixed results from faking studies (De Houwer et al., 2009).

Some limitations of the present research have to be mentioned. To avoid deviating too far from the original BIAT, we used a limited number of trials per condition (40 trials each). Therefore our scoring of the earlier components might be of limited accuracy (cf. Woodman, 2010). However, we used a peak area scoring for comparing differences on each component, which is found to be more reliable (Olvet and Hajcak, 2009) and thus are recommended in ERP research (Keil et al., 2014). Further, these results are found on the group level. The microvolt differences for both conditions were rather small. This corresponds to the overall doping attitude of our sample, which was only slightly negative (mean D-Score $= -0.24$). However, the correlations between the LPP and D-scores suggest, that the LPP differences might be underestimating the effects for the single subject with anti-doping attitudes. When only considering the two thirds of the sample with an anti-doping D-score, the LPP differences increase considerably [$t_{(26)} = 3.76$, $p < 0.001$, $d = 0.40$]. Future research should investigate if microvolt differences are bigger when participants hold a stronger attitude toward the target concept or attitudes toward a given concept are more homogenous. Finally, the potential inclusion of these results in meta-analyses warrants a note of caution. The doping attitudes investigated here were collected as baseline measures for two other studies that were concerned with investigating cerebral correlates of IAT faking (Schindler et al., 2015b; Wolff et al. in prep.). Thus, although these studies addressed different research questions, they rely on the same sample.

Summarizing the main findings, we could identify relatively early and presumably more automatic as well as late and more deliberate differences during BIAT completion. We had a sample of university students, which exhibited increased attention and faster reaction times for negative attitudes toward performance enhancing substances. Although, the enlarged occipital P2 for

negative doping attitudes might be seen as a proof of the automaticity of activated associations during a doping BIAT, it is important to acknowledge that only the late positive potential was found to be associated with BIAT scores. This provides preliminary evidence that there is, next to an implicit component, a deliberate component in performing a BIAT.

In regard to doping, these results provide a first indication on the cerebral processes that are associated with the doping attitudes that are captured by the BIAT. The possibility to identify neural correlates of the BIAT score along with previous findings that these scores are associated with actual doping behavior (Brand et al., 2014b) and the relative robustness of such measures toward faking (Wolff et al., 2015) lends further weight to the importance of such implicit attitudes for doping research.

There are at least three reasons why we believe that our results are of interest to the broader concept of performance enhancing substance abuse (which incorporates NE, doping and other variants of drug instrumentalization). First, from a theoretical level doping and NE are similar as they imply using a substance as a means to performance enhancement. This similarity has been shown specifically for attitudes already: A domain-specific adaptation of a doping attitude questionnaire has been found to be a valid predictor of NE behavior (Wolff and Brand, 2013). Second, from a measurement perspective the stimuli that represent doping in the doping BIAT are rather unspecific. They contain pictures of syringes and pills. It would thus be worthwhile to assess if this doping BIAT can be reframed to the NE context. Third, social desirability has been found to affect responding in NE self-reports as well (Dietz et al., 2013a) and the doping BIAT has been found to be relatively robust toward such self-presentation efforts (Wolff et al., 2015). We encourage further research to develop such indirect measures for the NE domain as well. This doping BIAT represents a measure that has been heavily scrutinized from various angles by recent research (Brand et al., 2014a,b; Wolff et al., 2015; Schindler et al., 2015b) and might provide a good starting point for such endeavors in the NE domain. Understanding of the cerebral roots of attitudes toward performance enhancing substances will be an important step in further unraveling the psychology of NE.

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Drugs As Instruments: Describing and Testing a Behavioral Approach to the Study of Neuroenhancement

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Neuroenhancement (NE) is the non-medical use of psychoactive substances to produce a subjective enhancement in psychological functioning and experience. So far empirical investigations of individuals' motivation for NE however have been hampered by the lack of theoretical foundation. This study aimed to apply drug instrumentalization theory to user motivation for NE. We argue that NE should be defined and analyzed from a behavioral perspective rather than in terms of the characteristics of substances used for NE. In the empirical study we explored user behavior by analyzing relationships between drug options (use over-the-counter products, prescription drugs, illicit drugs) and postulated drug instrumentalization goals (e.g., improved cognitive performance, counteracting fatigue, improved social interaction). Questionnaire data from 1438 university students were subjected to exploratory and confirmatory factor analysis to address the question of whether analysis of drug instrumentalization should be based on the assumption that users are aiming to achieve a certain goal and choose their drug accordingly or whether NE behavior is more strongly rooted in a decision to try or use a certain drug option. We used factor mixture modeling to explore whether users could be separated into qualitatively different groups defined by a shared "goal × drug option" configuration. Our results indicate, first, that individuals' decisions about NE are eventually based on personal attitude to drug options (e.g., willingness to use an over-the-counter product but not to abuse prescription drugs) rather than motivated by desire to achieve a specific goal (e.g., fighting tiredness) for which different drug options might be tried. Second, data analyses suggested two qualitatively different classes of users. Both predominantly used over-the-counter products, but "neuroenhancers" might be characterized by a higher propensity to instrumentalize over-the-counter products for virtually all investigated goals whereas "fatigue-fighters" might be inclined to use over-the-counter products exclusively to fight fatigue. We believe that psychological investigations like these are essential, especially for designing programs to prevent risky behavior.

Keywords: psychoactive drugs, non-addictive behavior, cognitive enhancement, drug instrumentalization, user types

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INTRODUCTION

Use of psychoactive drugs is common in most societies. Use of caffeine, alcohol, and nicotine is particularly widespread; illicit drugs such as cocaine or marijuana are consumed less frequently (Kandel et al., 1997). There is disproportionate growth in medically unsupervised use (i.e., abuse) of prescription drugs, particularly opioids and stimulants, especially among adolescents and young adults (Johnston et al., 2010; United Nations, 2011).

Psychological research on motivations for using psychoactive drugs is often concerned with addiction and theories of drug use often focus on addiction (e.g., O'Brien et al., 1992; Koob and LeMoal, 1997; Baker et al., 2004). Given the known costs of addiction, both for the individual and for society, it is clearly an important research target. Many drug users should not be considered addicted however; for example 95% of alcohol consumers (Anderson and Baumberg, 2006), around 92% of nicotine users (Baumeister et al., 2008) and 91% of caffeine users (Meredith et al., 2013) should not be considered addicted[1]. It is likely that similar figures apply to abuse of prescription drugs (United Nations, 2011).

The starting point for our investigation was the growing number of research articles on university students' use of psychoactive pharmacological products for the purpose of enhancing cognitive performance. It has been reported that 6-8% of university students in Germany (Middendorff et al., 2015) and perhaps the same or an even higher proportion in the United States (Smith and Farah, 2011, report a rather uninformative guestimate of 2–50%) have abused drugs such as Modafinil (a wakefulness-promoting drug usually prescribed to treat shift-work sleep disorder and narcolepsy) for this purpose. Recently the presumed motivation for such drug use has prompted research on the cognitive effects of pharmaceutical drugs (e.g., benchmarking effect sizes of different dopaminergics; Fond et al., 2015) as well as several nutraceuticals (e.g., Ginseng and Bacopa benchmarked against Modafinil; Neale et al., 2013) and the ethics of usage (e.g., whether safe pharmacological enhancement could help resolve societal inequalities; Glannon, 2015). Research on students' motivation to try and perhaps subsequently persist with using such performance enhancing substances is much less elaborated. This research aimed to investigate substance users' motivated behavior systematically, i.e., from a psychological perspective.

Drug Instrumentalization Theory

Drug instrumentalization theory (DI theory; Müller and Schumann, 2011a,b) suggests that non-addictive drug use can be explained in functional terms, as a purposeful, goal-directed process. For example the wakefulness-promoting prescription drug Modafinil might be used to enhance academic performance. It is a matter of fact, however, that some students prefer to use caffeinated, non-prescription products for this purpose (Franke et al., 2011). Others might know that a strong cup of filter coffee (Walsh et al., 1990) is at least as effective a stimulant as many caffeinated over-the-counter products and perhaps more so, and prefer this option. DI theory suggests that the starting point for explaining the non-addictive use of drugs should be to consider the purpose for which they are taken; before considering the specific characteristics of the various substances that could be used for that purpose. DI theory proposes a non-exhaustive list of goals relevant to instrumental drug use; these goals are presented in **Table 1** along with examples from the domains discussed here and in the following sections.

Another claim of DI theory is that repeated, non-addictive drug use should be modeled as a two-step process: "(1) the seeking and consumption of a psychoactive drug in order to change the present mental state into a previously learned mental state, which then allows for (2) better performance of other, previously established behaviors and better goal achievement" (Müller and Schumann, 2011a, p. 295). Whilst we largely endorse the proposed first step, we think that from a psychological perspective the second step needs readjustment with regard to the qualifier "better" that implies factual improvement in performance and goal achievement.

Subjective expectations are important determinants of human behavior (e.g., Armitage and Conner, 2001). We argue that the presumed functions of a substance are an essential factor in motivation and perhaps even more important than the chosen substance's subsequent effects on performance (Wolff and Brand, 2013). This behavioral approach (Wolff and Brand, 2013; Wolff et al., 2014; Brand and Koch, 2016) differs from more substance-based approaches adopted by other authors (e.g., Franke et al., 2014; Maier and Schaub, 2015). It is our view that—in the terminology of learning theory—drug use is reinforced by the *subjective state* that this behavior, which was intended as a means to an end, produces. This reinforcement is moderated by the physiological and other observable effects of the drug which thus influence subsequent usage; a drug which proves more effective in producing the desired goal might come to be used more frequently.

This account implies, however, that objectively "better" performance and goal achievement is not a necessary consequence of instrumental drug use. We therefore suggest modifying the proposed claim about how individuals instrumentalize drugs to: (1) the seeking and consumption of a potentially psychoactive drug with the aim of reinstating a previously learned mental state that allows for (2) subjectively enhanced goal achievement.

Instrumental Use of Psychoactive Drugs to Enhance Cognitive Performance: One Aspect of Neuroenhancement

One aim of this article is to embed the active debate on what has been called pharmacological "cognitive enhancement" (e.g., Hildt and Franke, 2013) in the broader context of DI theory's (Müller

[1] According to ICD criteria addiction (termed dependence syndrome by the WHO) is a "cluster of physiological, behavioral, and cognitive phenomena in which the use of substances takes on a much higher priority for a given individual than other behaviors that once had greater value. A central descriptive characteristic of the dependence syndrome is the desire to take the psychoactive drugs. There may be evidence that return to substance use after a period of abstinence leads to a more rapid reappearance of other features of the syndrome than occurs with nondependent individuals" (cited from "World Health Organization, Management of substance abuse, Dependence syndrome," last modified 2016, http://www.who.int/substance_abuse/terminology/definition1/en/).

TABLE 1 | Instrumentalization goals as proposed by DI theory (Müller and Schumann, 2011a,b) with behavioral examples.

No.	Instrumentalization goal	Label[a]	Behavioral example[b]
[1]	Improved cognitive performance	Cognitive performance	Using methylphenidate to feel more concentrated and alert
[2]	Counteracting fatigue	Fatigue	Using caffeine to counteract fatigue
[3]	Improved social interaction	Social interaction	Using alcohol or other drugs at parties to be more talkative, disinhibited, and self-confident
[4]	Facilitated sexual behavior	Sexual behavior	Using drugs like alcohol or cocaine to increase the likelihood of and pleasure during sexual intercourse
[5]	Facilitated recovery from psychological stress	Stress recovery	Using cannabis to recover from a stressful day at work
[6]	Coping with psychological stress	Stress coping	Using alcohol to reduce perceived stress level before an important meeting
[7]	Euphoria and hedonia	Euphoria	Using cannabis, alcohol, or other to induce intense well-being and positive feelings
[8]	Self-medication for mental problems	Self-medication	Using antidepressants, cannabis or alcohol to reduce depressive symptoms, regain control over one's mental state, and enhance functioning in everyday life
[9]	Sensory curiosity and facilitating spiritual and religious activities	Sensory curiosity	Using hallucinogenic drugs (e.g., MDMA) to facilitate spiritual experiences

[a] *Short labels for the goal detailed in the previous column.*
[b] *This list of examples is illustrative rather than exhaustive.*

and Schumann, 2011a,b) framework theory for non-addictive psychoactive drug consumption.

Enhancements can be tried with the aim of enhancing cognitive functioning (e.g., working memory, task flexibility) and enabling increased effort (e.g., in order to stay awake and study longer; see Zelli et al., 2015), aims which might be regarded as analogous to two of the DI theory instrumentalization goals, "improved cognitive performance" and "counteracting fatigue." One might try to attain these goals by using a suitable over-the-counter product, e.g., caffeine pills, herbal substances; however some people regard over-the-counter medication as being fine for mild or occasional symptoms but less suited to treatment of severe symptoms, for which more potent drugs are necessary (United Nations, 2011). These individuals might also believe that recognized medical drugs are safer than illicit drugs, even when used unsupervised and hence although they would be unwilling to try the illegal drug "speed" (amphetamine), they might decide to try Modafinil (a prescription drug) in an attempt to enhance cognitive performance or counteract fatigue.

It is obvious from this example that diverse substances can be used in pursuit of the same goal (equifinality). It is also possible to use a single drug as an instrument for attaining several different goals (multifinality); for example cocaine users report using this illicit substance to enhance cognitive performance, as well as to facilitate social interactions and induce euphoria (Boys et al., 2001). Research focused on the use or abuse of pharmacological products to enhance cognitive performance has so far largely neglected this second aspect, multifinality, of instrumental drug use (e.g., Mazanov et al., 2013; Franke et al., 2014; Sattler et al., 2014; Wolff et al., 2014).

This point, the widely neglected aspect of multifinality in the respective studies, calls into question current usage of the terms "cognitive enhancement." It unjustifiably narrows the phenomenon under investigation. Similar criticisms have been made by researchers who note that many of the substances used for "cognitive enhancement" are not very effective for this purpose (Zohny, 2015). We propose using the umbrella term *neuroenhancement* (*NE*) instead[2]. It is important to emphasize our suggestion that using this term in the proposed way thus refers to a *behavior* that is *explicitly connected* with a *specific goal*: We define this behavior, NE, as the non-medical use of psychoactive substances (and technology; e.g., Clark and Parasuraman, 2014) for the purpose of producing a subjective enhancement in psychological functioning and experience.

It is important to note that in pursuit of, for example, enhanced cognitive performance, individuals may instrumentalize any substance or technology which they think might help them to reach their goal. The attribution of relevant efficacy to the substance or technology is sufficient to qualify their behavior as attempted NE behavior and to investigate this behavior's motivational roots (Wolff and Brand, 2013).

This Study

Building upon the above-described argument, in the first stage of our empirical study we explored user behavior by analyzing patterns of relationships between chosen drug options ("over-the-counter products," "prescription drugs," and "illicit drugs"; e.g., Franke et al., 2014) and instrumental goals ("better cognitive performance and reduced fatigue," "better social interaction," "facilitation of sexual behavior," "enhanced recovery from and coping with psychological stress," "euphoria and hedonia," "more attractive physical appearance," "self-medication for mental problems," "sensory curiosity and facilitation of spiritual and religious activities"; Müller and Schumann, 2011a). We aimed to find and then confirm empirical patterns that would help us to address the question of whether NE behavior should be

[2] Although there is no evidence that (all) eligible substances actually enhance neural activity, the umbrella term's prefix "neuro-" seems to be acceptable here because of its widespread and established use in social science research.

considered a goal-directed behavior in which the choice of drug is predicated on its presumed functionality in relation to that goal or whether the choice of a drug option (e.g., an over-the-counter product but not an illicit drug) is primarily driven by other factors.

The second stage of our analysis explored whether users could be segregated into qualitatively different groups on the basis of the combination of the psychological variable "goal" and the attribute "drug option" (they were classified in these terms in the first stage). We did this because inter-individual differences are important when it comes to monitoring and preventing risky behaviors (cf. Kreuter and Wray, 2003; Rimer and Kreuter, 2006).

In summary, we hoped to make a theoretically informed contribution to the psychological literature which would help to define the boundaries of NE research and provide empirical evidence which could be used to inform programs targeting the misuse of problematic substances (e.g., Wilens et al., 2008).

METHODS

Study Sample

The focus here was on university students. A non-exhaustive manual search of the internet resources of public and private German, Swiss and Austrian universities yielded the email addresses of 853 student associations for study programs in Biology, Computer Science, Economics, Educational Sciences, English and German language and literature studies, Electrical Engineering, Health Sciences, Law, Mathematics, Medical Sciences, Physics and Psychology. These student associations were contacted and asked to distribute the link to our online questionnaire using their student mailing lists. We are unable to assess how many student associations from which universities actually complied with this request.

Participation was voluntary and no compensation was offered for participation. Participants were informed that they would be able to complete the questionnaire anonymously (i.e., without giving their name or contact address). They were also informed in advance that they could decide to stop working through the questionnaire at any time without disadvantaging themselves in any way and that their answers would not be stored unless they clicked the "send data" button at the end of the questionnaire. The study was carried out in accordance with recommendations of the ethical committee of the University of Potsdam.

In total, 2771 students began working through the questionnaire. Around 50% ($n = 1438$) completed it and sent us their answers. The mean age of this group of responders was 23.95 $\pm$ 5.43 years; 950 (66%) were women. We did not collect data on the study programs in which these participants were enrolled.

Measures

Drug instrumentalization was assessed separately for each goal. Participants were first asked if they had ever used any substance to achieve a given goal. Participants then responded to three dichotomous (yes/no) items relating to whether they had already used an over-the-counter product, a prescription drug or an illicit drug in pursuit of this goal. We decided to assess the goal "enhancement or rebuilding of cognitive performance" with two questions (one for the "enhancement of…" and one for the "rebuilding of…" aspect) as these statements reflect distinct processes; the goal "facilitated recovery from and coping with psychological stress" was treated similarly. Participants thus indicated their pattern of behavior with respect to 27 goal $\times$ drug option combinations. In the remainder of the article we will refer to this set of items as the DI questionnaire.

Statistical Analyses

All statistical analyses were conducted using the statistical programs R (R Development Core Team, 2013) and MPlus 7 (Muthén and Muthén, 2013). The factorial structure of drug instrumentalization as assessed by the DI questionnaire (instrumentalization goals $\times$ drug option) was explored using exploratory factor analysis (EFA; psych package; Revelle, 2014) and confirmed using confirmatory factor analysis (CFA; lavaan package, Rossel, 2012). The dataset was randomly split in half to allow for independent EFA and CFA. Model tests were done according to the guidelines of Beauducel and Wittmann (2005), Hu and Bentler (1999), and Heene et al. (2011). We looked at the global model test as well as the fit indices *RMSEA* (< 0.05), *SRMR* (< 0.08), and *CFI* ($= 0.95$). A robust *ML* estimator was used to correct for violations of multivariate normal distribution. Missing data were dealt with using the FIML method. After this the complete dataset was subjected to factor mixture model (FMM) analysis to determine whether the latent structure was person-homogeneous, in other words to find qualitatively different groups of users. FMMs have several advantages over traditional methods of latent class identification. Specifically, FMMs allow drug instrumentalization to be modeled as an individual difference variable within a CFA model (e.g., Leite and Cooper, 2010). FMMs can be used for the analysis of data with underlying continuous constructs whilst simultaneously modeling population heterogeneity as they incorporate categorical and continuous latent variables (Lubke and Muthen, 2005, 2007). The procedure we followed in calculating and reporting our FMM analysis has been described in more detail elsewhere (Ziegler et al., 2015).

RESULTS

Descriptive Statistics

Descriptive statistics for all investigated variants of drug instrumentalization are visualized as a heat map in **Figure 1**. First, descriptive statistics indicated that all investigated goals were instrumentalized by at least some of the sample (the goal instrumentalized by the smallest proportion was "improving physical appearance": 18.6%). Second, answers indicated that in this sample all three drug options were employed in pursuit of the goals we investigated. Third, there was large variation between the frequencies with which specific "goal $\times$ drug option" configurations appeared; for example 87.2% of our participants reported that they had used over-the-counter products to fight fatigue but only 0.6% reported that they had used prescription drugs to facilitate sexual encounters.

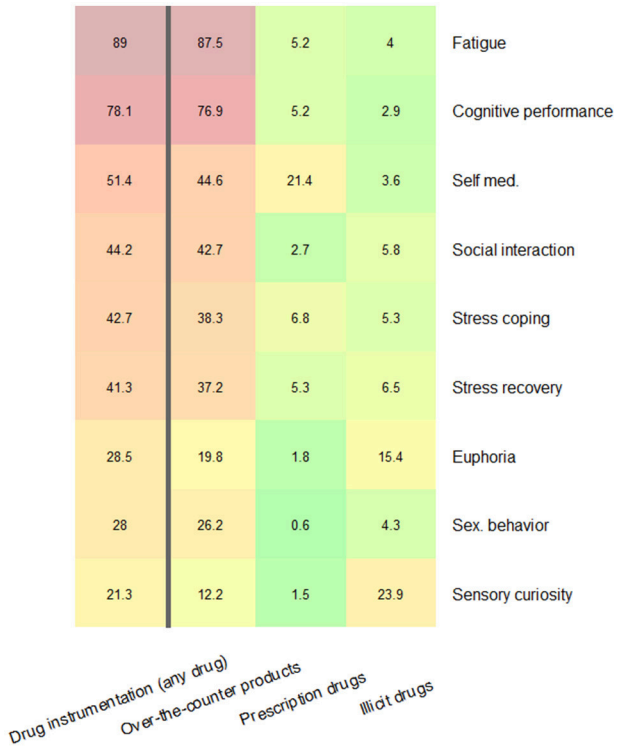

FIGURE 1 | Prevalence of instrumental use of drugs in pursuit of each goal irrespective of drug option (left column) and as a function of the three drug options (three right columns). Multiple positive responses were possible and therefore values in the colored columns do not add up to the values presented in the left column.

Factor Analyses

Parallel analysis (Horn, 1965) suggested that seven factors could be extracted. The minimum average partial test (Velicer, 1976) suggested a three factor solution. To choose a solution the two- to seven-factor solutions were extracted using principal axis factoring and geominT rotation with the R package psych (Revelle, 2014). The three-factor solution was the most plausible, reflecting patterns held together by the three drug options "over-the-counter products," "prescription drugs," and "illicit drugs." Factor loadings for this solution are given in **Table 2**. Consequently, in the subsequent CFA we tested this model, labeling the three factors "over-the-counter DI," "prescription DI," and "illicit DI." In the first step we tested the three measurement models for each factor separately, following advice by Ziegler and Hagemann (2015) according to which misfit within single measurement models might be harder to detect in the complete model otherwise. In each factor measurement model the nine items relating to whether a given drug option had been used to achieve specific goals were included in the analyses. The items and loadings for each factor measurement model are shown in **Table 3**. Analyses of model fit indicated that in all three cases measurement models described the data well (**Table 3**). We then added the same correlated residuals to all the measurement models ("fatigue" with "cognitive performance"; "euphoria" with "sensory curiosity") and ran a final analysis to assess the fit of the overall model (**Figure 2**). In order to achieve acceptable model fit three correlated error terms had to be included ("self-medication using prescription drugs" with "self-medication using over-the-counter drugs"; "sensory curiosity using illicit drugs" with both "sensory curiosity using of over-the-counter drugs" and "sensory curiosity using prescription drugs"). The fit indices for the complete model were $\chi^2 = 759.44$, $df = 312$, $p < 0.001$; $CFI = 0.90$; $RMSEA = 0.03$; $SRMR = 0.06$. This analysis indicated that the 27-item DI questionnaire was best be described by three drug option factors, each consisting of nine items with an identical format reflecting nine different aspects of drug instrumentalization and hence that drug instrumentalization behavior is primarily accounted for by the drug option rather than by specific instrumental goals.

TABLE 2 | The exploratory three-factor model for responses to the DI questionnaire.

Drug-types × DI goals	Factor 1	Factor 2	Factor 3	h^2	u^2
ILLICIT DRUGS					
… × Fatigue	0.70	0.24	−0.06	0.54	0.46
… × Stress coping	0.57	0.03	0.08	0.33	0.67
… × Stress recovery	0.60	0.08	−0.01	0.36	0.64
… × Cognitive performance	0.61	0.24	−0.03	0.43	0.57
… × Euphoria	0.65	−0.03	0.16	0.45	0.55
… × Sex. behavior	0.47	0.17	0.04	0.25	0.75
… × Self-med	0.44	0.02	0.08	0.20	0.80
… × Social interaction	0.54	0.07	0.16	0.32	0.68
… × Sensory curiosity	0.54	0.02	0.19	0.33	0.67
PRESCRIPTION DRUGS					
… × Euphoria	0.31	0.16	0.09	0.13	0.87
… × Sensory curiosity	0.38	0.04	0.15	0.17	0.83
… × Stress coping	0.09	0.80	0.07	0.66	0.34
… × Fatigue	0.24	0.61	−0.02	0.43	0.57
… × Cognitive performance	0.28	0.60	0.00	0.44	0.56
… × Social interaction	0.13	0.53	0.00	0.30	0.70
… × Stress recovery	0.05	0.45	0.13	0.22	0.78
… × Self-med.	0.08	0.38	0.14	0.17	0.83
… × Sex. behavior	0.24	0.31	0.02	0.15	0.85
OVER-THE-COUNTER SUBSTANCES					
… × Sensory curiosity	0.34	−0.04	0.33	0.22	0.78
… × Euphoria	0.24	−0.03	0.37	0.19	0.81
… × Stress coping	0.12	0.11	0.47	0.24	0.76
… × Stress recovery	0.14	0.11	0.39	0.19	0.81
… × Social interaction	0.21	0.07	0.38	0.19	0.81
… × Self-med.	−0.03	0.08	0.37	0.14	0.86
… × Sex. behavior	0.20	0.01	0.30	0.13	0.87
… × Fatigue	0.03	−0.05	0.46	0.21	0.79
… × Cognitive performance	0.03	0.00	0.47	0.22	0.78

Factor Mixture Models

Building on differentiation of our three latent factors of drug instrumentalization, the second goal was to investigate whether latent variables differentiating between types of instrumental drug users could be identified. Simply put, we were interested

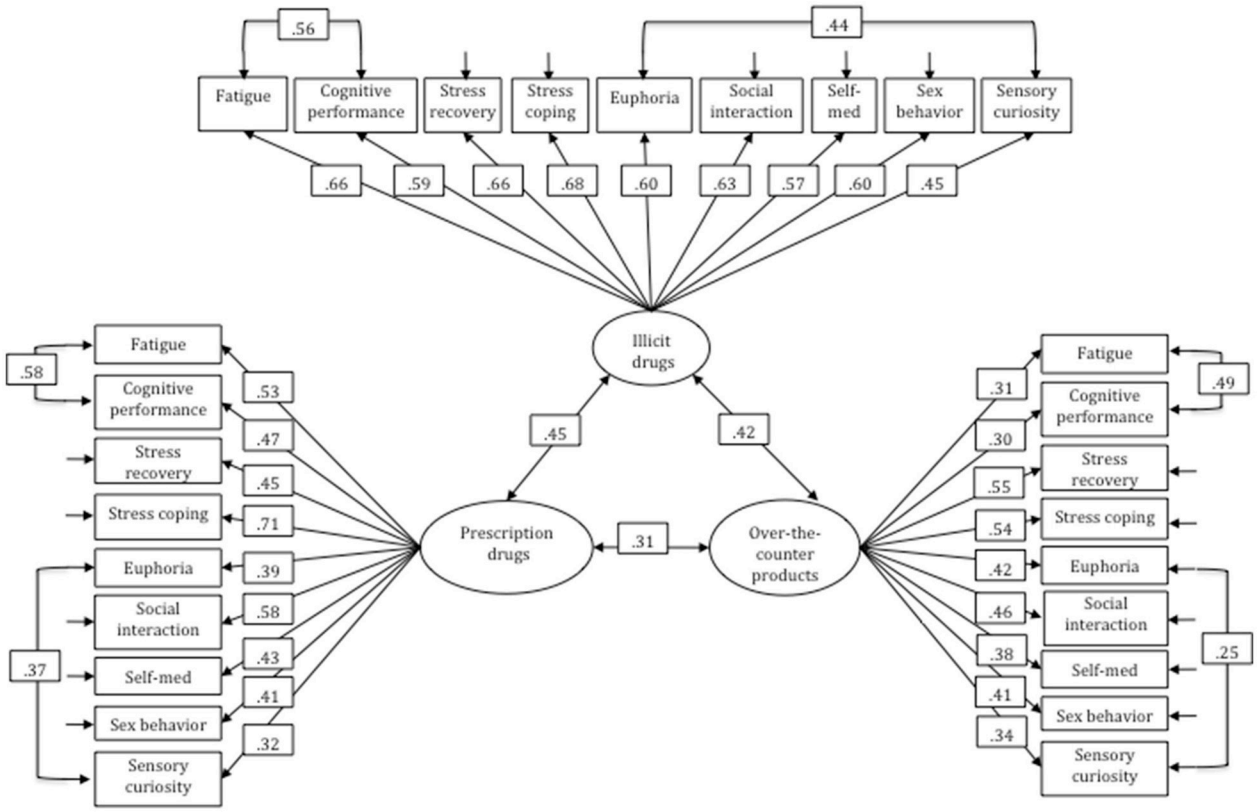

FIGURE 2 | The full three-factor model for DI behavior based on the CFA.

in whether qualitatively different classes of functional drug use could be identified with respect to each of the three drug options. Separate FMMs consisting of the nine items relating to use of each drug option (over-the-counter products; prescription drugs, illicit drugs) for DI were tested. Loadings on the latent usage variable were assumed to be equal for all classes in order to ensure that a similar latent variable was measured (factorial invariance). A robust maximum likelihood estimator was used to address the non-normality of the data. As to the acceptable model fits of the measurement models underlying these analyses (see **Table 3**) problems due to the exploitation of residual patterns are unlikely (Bauer and Curran, 2004). There was marginal evidence for the validity of a two-class solution, and only in the case of the over-the-counter DI factor (Lo-Mendel-Rubin test: $p = 0.058$; adjusted Lo-Mendel-Rubin test: $p = 0.059$)[3]. This suggests that we have two qualitatively different classes of users within the latent factor of over-the-counter products in our data. The values of the intercepts revealed that the average responses of the classes were different for almost all items. The first class (87.5% of the participants in our sample) could be described as having a higher propensity to use over-the-counter products in pursuit of diverse goals (**Table 4**); we termed this class of users "neuroenhancers." The second class of users had a generally lower propensity to use over-the-counter products (as indicated by the much lower intercept values in **Table 4**) and used over-the-counter products almost exclusively to fight fatigue; this class of users was termed "fatigue-fighters."

DISCUSSION

The aim of this study was to develop a theoretical conception of NE behavior that would account for original empirical data on drug instrumentalization among university students. The patterns of participants' responses to the DI questionnaire suggested that NE behavior is probably based on a primary decision about usage of a class of drugs (drug option).

In other words the EFA and CFA suggested that rather than identifying a goal or motivation (e.g., "I want to fight tiredness") and then instrumentally using the different drug options that might enable them to achieve this goal (e.g., to identify the most effective one) individuals seem to instrumentally use a given drug option and then accept the constraints this places on goal attainment (e.g., "I am willing to use over-the-counter products but not to abuse prescription drugs even if this limits how effectively I can fight my tiredness").

[3]We compared this two-class solution with a 1-class and a 3-class solution on the basis of a sample-size adjusted BIC. The lowest value occurred for the 2-class solution (11453.57), both other solutions were close together (1-class: 13141.95; 3-class: 13223.84). The 3-class solution had p -values of 0.23 for both Lo-Mendel tests. Taken together these tests support the validity of the 2-class solution.

TABLE 3 | Factor loadings for three CFA measurement models and fit indices for these models.

	Latent factor		
	Over-the-counter substances	Prescription drugs	Illicit drugs
STANDARDIZED FACTOR LOADINGS			
Fatigue	0.31*	0.48*	0.65*
Cognitive performance	0.30*	0.45*	0.62*
Stress recovery	0.57*	0.44*	0.62*
Stress coping	0.53*	0.68*	0.68*
Euphoria	0.46*	0.46*	0.61*
Social interaction	0.51*	0.62*	0.59*
Self-med.	0.39*	0.43*	0.55*
Sex. behavior	0.41*	0.39*	0.52*
Sensory curiosity	0.36*	0.35*	0.46*
FIT INDICES			
χ^2 (*df*)	80.44* (25)	166.22* (25)	68.33* (25)
CFI	0.93	0.92	0.98
RMSEA	0.056	0.087	0.05
SRMR	0.041	0.047	0.028

*$p < 0.05$.

TABLE 4 | Descriptive statistics for class solutions of the factor mixture models.

	Class I		Class II	
DI-Goals	**Intercept***	**S.E**	**Intercept***	**S.E**
Social interaction	0.432	0.014	0.350	0.050
Sex. behavior	0.269	0.013	0.183	0.042
Cognitive performance	0.879	0.009	−0.017	0.020
Fatigue	0.854	0.010	0.981	0.022
Stress coping	0.408	0.014	0.161	0.052
Stress recovery	0.383	0.014	0.244	0.059
Self-med.	0.457	0.014	0.333	0.052
Sensory curiosity	0.123	0.009	0.092	0.026
Euphoria	0.193	0.011	0.193	0.011

*$p < 0.001$.

Results from the FMM analysis can tentatively be interpreted as supporting the notion of two qualitatively different classes of users. Both of them predominantly used over-the-counter products; they were termed "neuroenhancers" and "fatigue-fighters." "Neuroenhancers" were characterized by a higher propensity to instrumentally use over-the-counter products for virtually all the goals specified in DI theory (improving cognitive performance and overcoming fatigue were endorsed with the largest propensity; **Table 4**). In contrast "fatigue-fighters" seemed to instrumentalize over-the-counter products solely for fighting fatigue. No comparable qualitative difference in patterns of usage was found among users of prescription drugs and illicit drugs.

DI theory provided the framework for this research. We started by asking participants about their instrumental use of over-the-counter products and their abuse of prescription and illicit drugs for the goals specified in DI theory. We did not ask about any other kind of drug use. In our sample of university students we found evidence that in the group of participants all drug options were used for all the proposed goals. In our view this finding corroborates one of the central claims of DI theory, namely that individuals' instrumental use of drugs cannot be adequately explained—or investigated—without addressing the specific goal(s) which motivated this use. Although users might respond positively when asked if they have used a given drug to enhance their cognitive performance, other co-existent goals might better account for their behavior. Studies of people's motivations or reasons for using drugs that they believe have the potential to enhance cognitive performance should therefore not be limited to consideration of this particular goal. This study revealed that *multifinality*, i.e., using one instrument to pursue several goals, is an important pattern of behavior in the context of use of psychoactive substances to produce a subjective enhancement in psychological functioning and experience, i.e., neuroenhancement.

Discussion of Factor Analyses Results

Factor analyses revealed the existence of three drug option-related factors, over-the-counter product DI, prescription drug DI, and illicit drug DI, but no goal-related factors. The various instrumentalization goals appeared in each of the three drug option factors instead. This indicates that participants' primary decision related to the drug option(s) they were willing to use instrumentally. In practice this meant that if, for example, an individual resorted to using an over-the-counter product in an attempt to enhance cognitive performance then he or she was more likely to use over-the-counter products in pursuit of some other goal. An alternative pattern of results would have been that the primary decision was about which goal to pursue via use of drugs and secondarily what drug option might be the most effective tool for achieving that goal. Such a pattern would have been reflected in a set of factors representing different instrumentalization goals (or patterns of goals). A third possibility is that there might have been systematic links between drug options and specific goals, e.g., the use of over-the-counter products for facilitation of social interaction and using prescription drugs for facilitating sexual encounters. We did not observe this kind of goal-dependent switching between drug options in our sample. Our preliminary, cautious interpretation of these results, in terms of instrumental (i.e., means-end) drug use, is that individuals use drugs as instruments for pursuing a variety of goals, but that willingness to instrumentalize a drug option takes priority over attainment of a specific goal in the decision-making process. Although we found marked differences in the frequency with which specific drug options were chosen as tools for pursuing specific goals on a descriptive level, factor analyses revealed that there was more consistency in the type of instrument an individual chose, irrespective of goal. It is possible that individuals' attributions of functionality are general to a drug option and aligned with their usage behavior, for example, an individual who believes that only prescription drugs are both powerful and safe enough to allow to enable one to attain one's objectives might use methylphenidate (instead of a simple energy drink) to enhance his or her concentration and would similarly choose to use prescription antidepressants (rather than

Ginkgo biloba products) to enhance his or her subjective quality of life.

Generally speaking, one result is that the observed variance-covariance matrix was best explained by three correlated factors representing the three different drug options. The more inclined an individual is to use a given drug option for one specific goal, the more likely it is that he or she will choose the same option as an aid to attaining other goals. In contrast, a willingness to use one option as an instrument for attaining a specific goal, e.g., an over-the-counter product to facilitate sexual behavior, does not imply a similar willingness to use other options, e.g., illicit drugs, in pursuit of that goal.

Discussion of Factor Mixture Modeling Results

We found some support for the idea of two different user classes for over-the-counter products. The two classes could be described in terms of "neuroenhancers" and "fatigue-fighters." The possible existence of two qualitatively different classes of user indicates that individuals differ not only with respect to what options they are willing to use for DI—as the factor analyses showed—but also, in the case of use of over-the-counter products, with respect to what goals they pursue using drugs. The class of participants who were inclined to use drugs in pursuit of a variety of goals (the neuroenhancers) seems to see drugs as effective instruments for pursuing the rather general goal "modulation of performance." The second class seems to consist of individuals who only use drugs as instruments for "staying awake" (the fatigue-fighters) and largely abstain from other forms of instrumental drug use.

We suggest—although at this stage it is only a hypothesis—that "neuroenhancers" use drugs proactively, and truly as enhancers i.e., in pursuit of supra-normal performance, whereas "fatigue-fighters" use drugs more reactively, as a means of overcoming a deficit (sub-normal performance). In future research it will be interesting replicate the two class solution we observed and to investigate the drivers behind (these) different patterns of behavior.

Latent classes were only identified within the over-the-counter product DI factor. At present we can only speculate about why no latent classes were identified within the other DI factors. One possible reason is that instrumental use of prescription and illicit drugs is a more socially sensitive behavior than instrumental use of over-the-counter products (Dietz et al., 2013) and thus we failed to detect latent user classes within the other DI factors because participants did not report their use of these drug options truthfully. Similarly, the low rates of use of these drug options might have made it impossible to distinguish different classes of users. In our sample the reported prevalence of drug use in pursuit of the DI goals more directly related to academic performance (counteracting fatigue, enhancing cognitive performance, stress recovery) was comparable with previous reports (cf. McCabe et al., 2005; Mache et al., 2012). In our opinion there is a second plausible explanation for the failure to detect different latent classes of user in the cases of prescription and illicit drugs. Given the generally lower prevalence of DI using prescription drugs and illicit drugs, it is possible that different classes of latent user have simply not yet emerged in society. This might be because the only legally obtainable drugs which are generally known as instruments for attaining the various goals specified in DI theory (regardless of their actual efficacy) are over-the-counter products. In other words the university students in our sample might consider themselves "experts" on DI with over-the-counter products but not with the other drug options. In future research it would be interesting to investigate whether "knowledge about drugs" and "drug availability" emerge as latent classes in analysis of DI.

Drug Instrumentalization in This Sample

Our sample was a self-selected convenience sample of university students and therefore does not permit inferences about the general population. Nevertheless, our recruitment strategy targeted students studying the most popular academic subjects in Germany, Switzerland and Austria; we were thus able to recruit a large, diverse sample of university students.

We found empirical support for instrumental use of drugs in pursuit of all the goals specified in DI theory. The reported lifetime prevalence of use of any drug in pursuit of goals varied enormously between goals. The majority of our participants had used drugs as instruments to counteract fatigue (89.0%) and enhance cognitive performance (78.1%). Drug instrumentalization with respect to certain goals seems to be the norm amongst the student population, whereas instrumental use of drugs in pursuit of others is relatively uncommon. One straightforward explanation for these differences is that some goals were of greater personal importance to our sample than others. This might also account for the recent spike in public attention (e.g., Partridge et al., 2011; Rath, 2012) and scientific attention to performance enhancement and its reported prevalence in academia (e.g., Maher, 2008). The two goals most commonly pursued via drugs in our study are very closely linked to the domain of structured learning. The relative frequency of instrumental drug use in pursuit of these goals might simply reflect the heightened importance of academic performance in society.

An alternative explanation is that the observed differences in how frequently goals are pursued via drugs reflect subjective perceptions of what drug options are most effective for which goals. The drug options most frequently used for all the goals we investigated was over-the-counter drugs. The most frequently targeted goals might represent those which folk psychopharmacology connects most closely with over-the-counter products, namely "overcoming fatigue," "improving cognitive performance," "coping with stress," "recovering from demands," and "facilitating social interaction." Prescription drugs were used most frequently for "self-medication" and illicit drugs were used most frequently for "sensory curiosity." There is intuitive appeal to this account, as it implies that individuals choose substances that are generally thought to be effective for the goals in which they are interested. If one wants to self-medicate for mental problems, prescription drugs are the most promising candidate as they are marketed (and designed) as effective treatments for mental problems. Similarly, illicit

substances are commonly perceived as a good way of attaining a euphoric state.

A very important issue that needs to be resolved by further investigations however is that moral intuitions, perceptions about cultural tolerance and acceptable risk-taking, together with institutional and societal ambivalence to enhancing substances (and illicit drugs especially) might differ between countries and cultures. The phenomenology we found in our European sample might not correspond with the situation in Arab countries (e.g., Wolff et al., 2016). Cross-cultural comparisons should be conducted to shed light on this.

Limitations

This study used DI theory as the basis for research into the psychology of drug instrumentalization. We feel our results provide some important insight into the kinds of means-end (i.e., instrumental action-goal) relationship. Some limitations of the research should, however, be discussed along with questions that remain to be addressed in future research.

Goals and drug options might differ in terms of their social desirability and hence the extent to which relevant behavior is over- or under-reported. Randomized response technique (RRT, Greenberg et al., 1969) is a method of maximizing respondent anonymity in order to reduce the impact of social desirability bias on responses. This method was not suitable for our purposes as it is impossible to infer affirmation or denial of a certain behavior on the individual level from this type of data. We could not have investigated the factorial structure of drug instrumentalization or identified latent drug use classes with data collected using RRT. Use of indirect indicators is another option for dealing with social desirability bias (Greenwald et al., 2009), for example, the Implicit Association Test (Greenwald et al., 1998) has been shown to be valid predictor of athletes' doping test results (Brand et al., 2014) that is hard to distort (Wolff et al., 2015). Further studies should investigate whether indirect tests are needed or helpful in acquiring valid self-report data on NE behavior.

We did not ask for information about exactly which drugs university students had used for drug instrumentalization. We were thus not able to make assessments on specific substances. DI behavior seems to be driven largely by an individual's perception of the functions of a drug option rather than by its objective functional profile. This does not imply that future studies should refrain from assessing the use of specific drugs. Information about what drugs are perceived as effective instruments for attaining certain goals would be valuable.

It has been shown that FMM analyses can yield artificial solutions in case of non-normality or when ill fitting models are analyzed (Bauer and Curran, 2004). Even though the models analyzed here had acceptable model fit and a robust maximum likelihood estimator was used, the results should be interpreted with care. The 2-class solution fit better than a 1- or 3-class solution. Still, the direct test of significance was only marginally significant with the given sample size. Moreover, considering our questionnaire format, it cannot be ruled out that minor dependencies between items occured. Considering the explorative nature of this study as well as the high plausibility of its findings, the 2-class solution should be regarded as a feasible working hypothesis at least. Thus, future research should replicate our finding trying different questionnaire formats and more diverse samples.

Practical Implications and Conclusion

Knowing what an individual hopes to achieve by using a drug enables one to take a more informed approach to dealing with such behavior; this might involve endorsement, monitoring, preventive strategies, treatment, or prohibition. For example, use of an illicit drug for self-medication might warrant a different response from use of the same drug for hedonistic purposes. Another issue is that ethical evaluation of different DI goals might be perceived ambiguous in parts of the society. For example doping in sport (although not yet explicitly labeled as a DI behavior) is widely seen as unethical and is the target of widespread public disapproval. There is at present no definitive ethical verdict on the most prevalent form of DI, namely use of drugs in pursuit of enhanced cognitive performance (e.g., Farah, 2012; Caviola et al., 2014; Maslen et al., 2014). Our results elucidate the complex psychological processes underlying NE. It is likely that there are various forms of NE; regardless of whether one analyzes behavior according to the type of drug or drug option involved or behavior according to the goal pursued. When dealing with somebody who abuses Ritalin it is important to know whether the aim is deficit recovery or mitigation (i.e., to cope with and recover from academic demands) or enhanced performance (in this example supra-normal concentration). Unregard of the pursued purpose abusing this drug is a problem. But the arguments needed to convince a person to refrain from this abuse might be different.

In conclusion the aim of this article was to propose to, first, consequently account for the motivational roots of NE behavior in future investigations. Second, we feel that the proposed approach to the research topic, namely defining NE as the non-medical use of psychoactive substances for the purpose of producing a subjective enhancement in psychological functioning and experience, will help to overcome the conceptual limitations which have hampered research dedicated to the abuse of pharmacological products for the purpose of enhancing cognitive performance thus far (Zohny, 2015). Last but not least, we have provided empirical evidence that university students using NE might be classified according to their motivation or goal, e.g., "neuroenhancers" or "fatigue-fighters" and that this captures fundamental differences in NE behavior. We believe that such forms of differentiation between users are essential to devising techniques for deterring risky behavior among university students.

AUTHOR CONTRIBUTIONS

RB and WW developed this research question. WW conducted the empirical part of the study. RB, WW, and MZ jointly analyzed the data and cooperatively wrote this report.

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Using Caffeine Pills for Performance Enhancement. An Experimental Study on University Students' Willingness and Their Intention to Try Neuroenhancements

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Recent research has indicated that university students sometimes use caffeine pills for neuroenhancement (NE; non-medical use of psychoactive substances or technology to produce a subjective enhancement in psychological functioning and experience), especially during exam preparation. In our factorial survey experiment, we manipulated the evidence participants were given about the prevalence of NE amongst peers and measured the resulting effects on the psychological predictors included in the Prototype-Willingness Model of risk behavior. Two hundred and thirty-one university students were randomized to a high prevalence condition (read faked research results overstating usage of caffeine pills amongst peers by a factor of 5; 50%), low prevalence condition (half the estimated prevalence; 5%) or control condition (no information about peer prevalence). Structural equation modeling confirmed that our participants' willingness and intention to use caffeine pills in the next exam period could be explained by their past use of neuroenhancers, attitude to NE and subjective norm about use of caffeine pills whilst image of the typical user was a much less important factor. Provision of inaccurate information about prevalence reduced the predictive power of attitude with respect to willingness by 40-45%. This may be because receiving information about peer prevalence which does not fit with their perception of the social norm causes people to question their attitude. Prevalence information might exert a deterrent effect on NE via the attitude-willingness association. We argue that research into NE and deterrence of associated risk behaviors should be informed by psychological theory.

Keywords: attitude, prevalence information, prototype-willingness-model, social reactivity, doping

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INTRODUCTION

Neuroenhancement (NE) is non-medical use of psychoactive substances or technology for the purpose of producing a subjective enhancement in psychological functioning and experience (Jongh et al., 2008; Mueller and Schumann, 2011; de Berker et al., 2013; Kipke, 2013; Clark and Parasuraman, 2014; Farah et al., 2014; Maier and Schaub, 2015, for elements of this definition). Sometimes the term 'pharmacological cognitive enhancement' is used to refer to the use of psychoactive drugs to enhance psychological capacities such as attention, concentration, and

memory (e.g., Franke and Lieb, 2010; Dietz et al., 2013). The performance-enhancing effects of drugs used as neuroenhancers seem to be limited, regardless of whether they are prescription drugs such as methylphenidate (Ritalin), mixed amphetamine salts (Adderall) and modafinil (Provigil); illicit drugs (e.g., amphetamine, cocaine, ecstasy) or over-the-counter products (e.g., caffeinated drinks, energy drinks, *Ginkgo biloba*; e.g., Franke et al., 2014). Given the considerable overlap between the inconsistent cognitive effects of most of these substances on cognitive capacity and their incidental mood- and motivation-related effects (e.g., Ilieva et al., 2013) describing them as 'cognitive enhancers' may be overly narrow and restrictive (Zohny, 2015).

Wolff and Brand (2013) pointed out that information about the type and effects of a substance does not explain why people do or do not experiment with neuroenhancers. They argued that motivation to experiment with neuroenhancers could be explained by expectations about their effects. Someone drinking a strong cup of coffee explicitly in order to stay awake and thus study for longer or to enhance specific cognitive capacities (e.g., attention, recall memory) thus provides an adequate example of attempted NE. In this article, we will treat NE as goal-directed behavior intended to produce an improvement in academic performance.

There is an active debate about the ethics and pros and cons of NE at present and in the future (e.g., Hildt and Franke, 2013). Scientists remind us not to overestimate the effects of substances used as neuroenhancers (e.g., Franke et al., 2014; Zohny, 2015), but the market for substances (e.g., soft-drinks) promising an energy boost, or cognitive benefits as well as mood enhancement (Ishak et al., 2012) is increasing. In the light of these developments it is especially important to avoid fuelling the media hype surrounding NE (Partridge et al., 2011) and to state clearly the aims and limitations of published research. This paper is on the psychology of NE. We intend to describe and analyze university students' motivation to experiment with NE in terms of a social cognitive theory of behavior.

Prevalence of NE in Academia

There is limited reliable evidence on prevalence of NE in academia. Extant studies differ with regard to underlying definitions (e.g., whether NE is restricted to use of prescription drugs), representativeness of the sample (*ad hoc*; random), the types of substance considered (over-the-counter preparations; prescription drugs; illegal substances), data collection method (e.g., extent to which the confidentiality of self-reports is guaranteed) and time period investigated (e.g., point vs. life-time prevalence; Franke et al., 2014). Based on self-report questionnaires administered to large samples it has been reported that 5% in the year 2010/2011 (Middendorff et al., 2012) and 6% in 2014/2015 (Middendorff et al., 2015) of German university students abuse prescription drugs or illicit substances for "brain doping" during their years of study. Estimates of prevalence based on randomized response techniques that help to ensure the confidentiality of responses vary from 4% (Middendorff et al., 2015) to as much as 20% for 1-year prevalence in a study including caffeine pills as a neuroenhancer (Dietz et al., 2013). This latter figure is very similar to the reported abuse of prescription drugs for NE by research professionals (Maher, 2008). Maher reported that 20% of *Nature* readers from 60 nations who responded to an informal survey confessed to having used a prescription drug for NE at least once; however, Wiegel et al. (2015) reported that the lifetime prevalence of self-reported NE in a large sample of German university teachers and professors was only 1%.

This study focused on university students' use of caffeine pills for NE. To date there has been only one pilot study of university students' use of coffee, caffeinated drinks, and caffeine pills in Germany (Franke et al., 2011). The authors concluded that 10.5% of university students had used over-the-counter caffeine pills as neuroenhancers on at least one occasion.

Psychological Factors Explaining NE in Students

Several studies have analyzed students' motivation for NE. Eickenhorst et al. (2012) investigated German university students' motives for using prescription drugs and illegal substances as neuroenhancers. The main motives reported by their participants were a desire to enhance concentration and alertness or to increase cognitive functioning in general; to enable them to relax, cope with stress and withstand performance pressure and a fear of being disadvantaged if they did not use such substances. Middendorff et al. (2012, 2015) reported that when interviewed most students indicated that their main motive for NE was to maintain, rather than enhance performance and that use of prescription drugs and over-the-counter products was particularly frequent during exam preparations.

Some authors have tried to go beyond descriptions of users' motives and elucidate the psychological processes underlying NE behavior. Wolff and Brand (2013) regressed students' NE behavior (use of prescription drugs and over-the-counter products) on their underlying positive attitude to NE and Sattler and Wiegel (2013) reported that six-month prevalence of prescription drug NE was higher in students with high test anxiety.

Three studies investigated the influence of selected psychological factors on participants' decisions about trying NE using online factorial questionnaires (pseudo-experimental designs; see "Materials and Methods" section in this article). Sattler et al. (2013b) explored university students' and teachers' rationales for use of neuroenhancers using a hypothetical scenario in which they systematically varied several variables (indicated in italics): "A university [teacher/student] considers trying to enhance his cognitive performance for his [work/studies] by using a prescription drug which he does not require on medical grounds. He would be able to get the pills for free. A study that found that there is a *60 percent* chance that the drug will improve cognitive performance by *250 percent* caught his attention. The side effects were investigated: using the medication causes *slight* headaches in *one out of 100,000* users. Possible additional side effects are *unknown*." Participants were asked to rate how willing they would be to use the substance described for NE if they were in the position of the person in

the scenario. The authors controlled for several factors which they thought might influence decisions (e.g., moral evaluation of NE, conceptualized as the participant's internal norm). The authors, e.g., found that the probability and severity of side-effects were negatively associated with willingness to use NE; internalization of social norms against use of neuroenhancers was also negatively associated with willingness to use NE. Sattler et al. (2013a) reported that NE was subject to a contagion effect: peer pressure (apparently high prevalence of substance use amongst peers) increased participants' willingness to use NE whereas formal prohibition and provision of information about health side-effects decreased willingness. Sattler et al. (2014) investigated drivers of and obstacles to drug use in university students from the perspective of economic decision theory, assuming that decisions about NE would be based on a rational evaluation of the probability that a substance would help users attain their goals. Two thirds of their participants staunchly refused to use a prescription drug for NE, a similar proportion to that found in the two previous studies (Sattler et al., 2013a,b). Low intrinsic motivation, high test anxiety and previous use of drugs for NE were associated with greater willingness to use NE in the future. As in earlier studies willingness to use neuroenhancers was negatively associated with high internalization of social norms against NE (i.e., moral disapproval of NE; see above) and positively associated with apparent peer prevalence.

Call for Theory-Driven Analysis of NE Behavior

Neuroenhancement is a multifaceted phenomenon (e.g., goals; factors governing decisions about use) that requires explanation at several levels (e.g., personal; social; environmental) based on a sound understanding of underlying psychosocial processes (e.g., evaluation of peer behavior). To date, however, most psychological research has been limited to identifying variables correlated with use of neuroenhancers and appears not to have been informed by psychological theory. Theory is an essential element of behavioral research; in particular the development of effective interventions is underpinned by explanatory models of behavior (Fishbein and Cappella, 2006). Experimental testing of theoretically derived hypotheses is superior to theoretically less-informed approaches, because it minimizes the risk of encountering arbitrary effects and overestimating the influence of variables (e.g., because of variable and case sampling errors).

This study aimed to address this research gap. It was based on the empirical findings from earlier psychological studies, but used an established theory of behavior to derive a model of the psychological determinants of NE behavior (cf. Zelli et al., 2015). Two other studies have used psychological theory to inform analyses of NE behavior. Wolff et al. (2014) used Job Demands Resources Theory to show that use of NE had a negative impact on university students' psychological perceptions of academic demands and interfered with their intrinsic motivation and Wolff et al. (2013) used the strength model of self-control to predict first use of NE. This study tested predictions derived from the Prototype Willingness Model (PWM; Gibbons et al., 1998). We investigated how information about peer behavior influenced associations between the psychological variables predicting university students' willingness and intention to use caffeine pills to enhance cognitive performance.

The Prototype-Willingness Model

At the core of the PWM (Gibbons et al., 1998) is the idea that sometimes persons will find themselves in situations which facilitate but do not compel particular behaviors. The model postulates that under such circumstance behavior is determined by the individual's willingness to perform the behavior in question rather than by a process of reflection with resulting plans and an intention at its end. Gibbons et al. (1998) defined willingness as an individual's openness to risk opportunity, i.e., to perform a risky behavior in the absence of a specific plan or intention to do so. Although willingness may be accompanied by a congruent intention this is not necessarily the case. According to the PWM willingness is a foundation from which overt behavior can emerge spontaneously and it can, at least temporarily, sustain that behavior (Gerrard et al., 2008).

The PWM is rooted in empirical analyses of adolescent risk-taking behavior and developmental health psychology theory. The model suggests two pathways for behavioral regulation, the reasoned pathway, which culminates in an intention and the social reactive pathway, from which a degree of willingness emerges. The two pathways are connected in various ways, most importantly through a postulated predictive relationship between willingness and intention (but not *vice versa*). The PWM is illustrated in full in **Figure 1**.

The PWM assumes that future behavior is informed by past behavior. The variable 'past behavior' is a factor in all processes or steps of both the reasoned and social reactive pathways, which respectively, influence 'willingness' and 'intention' to perform a given behavior (Gibbons et al., 2009).

All variables in the reasoned pathway are drawn from the Theory of Reasoned Action (Fishbein and Ajzen, 1975, 2010) which treats 'attitude' as the sum of evaluations of a psychological object captured by evaluations of attribute dimensions such as good-bad, harmful-beneficial, pleasant-unpleasant and likeable-dislikable (Ajzen, 2006). Another variable involved in the reasoned pathway is 'subjective norm,' which is defined as the perceived social pressure to engage or not engage in a given behavior. The PWM refers to descriptive norms (Gibbons et al., 1998). Items used to assess subjective norms should therefore capture individuals' perceptions of what significant others do (e.g., "Do you think your peers would use caffeine pills to enhance cognitive performance?") rather than what significant others think the respondent should do (injunctive norm; e.g., "Do you think that your peers would accept you taking caffeine pills for cognitive enhancement?"). 'Intention,' which is the PWM's most proximal predictor of behavior of the reasoned pathway, is based on a combination of attitude and descriptive norm.

The social reactive pathway is defined by certain variables' relationships with willingness. 'User prototype' is one of these variables. Gerrard et al. (2008) recommended that this variable should be measured using items such as "Take a moment to think about what kind of student in your age group uses caffeine pills to enhance cognitive functioning. We are not interested in anyone

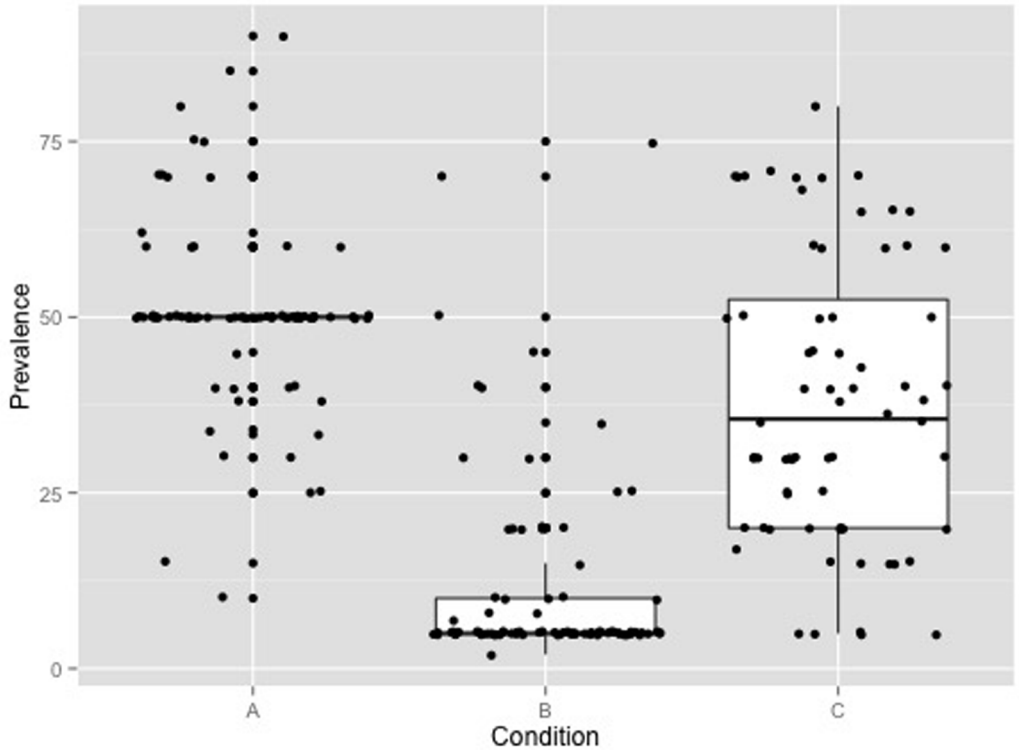

FIGURE 1 | Raw data and boxplots for participants' answers to the question in manipulation check 1 ("According to recent research what percentage of university students in Germany have used caffeine pills at least once to enhance their performance and improve their learning?") in experimental conditions A (50% peer prevalence), B (5%), and C (no information on peer prevalence).

in particular, just the typical person of your age who could do this. How [popular/smart/selfish] is this person?" In the context of the PWM a 'user prototype' is thus the sum of the characteristics of an imagined peer who engages in the target behavior (e.g., the 'typical' smoker). The social acceptability of a user prototype is positively associated with willingness to engage in the target behavior. 'Subjective norms' influence behavior via the reasoned pathway (through their association with 'intentions') and via the social reactive pathway, where they are postulated to be associated with 'willingness.' The socially reactive nature of the willingness construct is underscored by Gerrard et al.'s (2008) recommended items for measuring it, e.g., "Suppose you were studying with a group of friends and there were caffeine pills available. How willing would you be to take one?"

In the past few years, research on the PWM has accumulated in health psychology and a meta-analysis was published very recently (Todd et al., 2014). One of the conclusions from this meta-analysis was that the predictive power of the relationships postulated by the PWM is only marginally better in adolescent samples ($R^2 = 0.33$) than in adult samples ($R^2 = 0.29$), suggesting that although the model was developed to predict risk-taking behavior in adolescents it may be just as useful for predicting adult behavior. It is important to note that the meta-analysis did not test the full set of relationships involving PWM variables; it focused on the postulated correlations between prototypes, willingness and intentions and thus corroborated the postulated processes of the social reactive path. Most importantly the meta-analysis revealed that although willingness and intention are sometimes highly correlated they also act as independent predictors of risk behavior. Willingness explained an additional 4.9% of variance in behavior after intentions had been taken into account (Todd et al., 2014). The postulated correlations between variables in the reasoned pathway have been tested in several other PWM-related studies (e.g., the association between past behavior and attitude, Gibbons et al., 1998; pairwise associations between norms and intentions and willingness, Gerrard et al., 2008) and in meta-analyses which have confirmed the pattern of relationships among attitude, norms, intentions, and behavior (Armitage and Conner, 2001) postulated in the Theory of Planned Behavior (Ajzen, 1991).

Astonishingly, however, there is a dearth of empirical analyses of the full set of PWM variables using, e.g., multivariate model testing methodology.

This Study

Neuroenhancement research (e.g., Wolff and Brand, 2013; Schelle et al., 2014), research in related domains (e.g., doping in sport, Ntoumanis et al., 2014) and behavior change research more generally (e.g., McEachan et al., 2011) have shown that variables used in social cognitive theories, especially attitude, perceived social norms, and intentions (e.g., Fishbein and Ajzen, 1975, 2010), are important psychological predictors

of behavior. Recently university students' willingness to use psychoactive substances for performance enhancement emerged as an empirically useful dependent variable in NE research (e.g., Sattler et al., 2013b). The PWM is a comprehensive psychological theory of behavior that integrates all these variables. The PWM postulates two interacting pathways of behavioral regulation: the reasoned action path, in which attitudes and norms predict intention (the most proximal predictor of behavior) and the social reactive path, which integrates information from prototypes, attitudes, and norms to form another proximal predictor of behavior, i.e., behavioral willingness. The PWM thus represents an integrative psychological framework for the study of NE behavior.

Earlier research indicated that 10% of German university students use caffeine-containing products with the purpose to enhance cognitive performance on at least one occasion during their student life (Franke et al., 2011). Use of drugs for NE carries health risks (Schermer et al., 2009) and students consider it a risky behavior (Sattler et al., 2014). Peer behavior and peer pressure have been shown to be factors in university students' decisions about use of enhancers (Sattler et al., 2013a).

In our investigation, we sought to manipulate groups of university students into believing either that use of caffeine pills for NE was rather widespread amongst their peer group (experimental condition A: prevalence given as 50%; i.e., five times more than the actual estimated prevalence) or rare (condition B: prevalence given as 5%; i.e., half the estimated prevalence). A third group received no information about prevalence and served as a control group (condition C). We investigated use of caffeine pills specifically. Caffeine is available in over-the-counter products and in higher doses as a prescription drug. We deliberately restricted our investigation to use of caffeine in pill form, because we assumed that such products were more likely to be seen as 'pharmaceuticals' than, for example, caffeinated energy drinks which might be perceived as an everyday consumable.

First of all, we tested whether the PWM could be used to describe university students' willingness and intentions with respect to use of NE. Our second research question was based on the assumption that university students would have some sort of subjective perception of the prevalence of NE in their peer group and that this perception would shape their thinking about NE. We explored whether experimentally manipulating information about the prevalence of use of caffeine pills for NE amongst peers (high prevalence; low prevalence; no prevalence information) would influence the behavioral determinants specified in the PWM (attitude, subjective norm, user prototype, willingness, and intention) and the associations between these variables and willingness or intention to engage in the target behavior.

MATERIALS AND METHODS

This study was conducted online as a factorial survey experiment (Jasso, 2006). This method enables the researcher to determine the influence of experimentally manipulated information on respondents' self-reported thoughts, feelings, and decisions. The Questback EFS 10.6 software was used to run the experiment. The questionnaire was presented in German (i.e., all example items below are English translations from the German originals). The access link was distributed via Facebook and email thus creating a convenience sample drawn from the target population, university students in Germany. Data collection started in March 2015 and ended 3 weeks later in April 2015. The study was carried out in accordance with the recommendations of the ethical committee of the University of Potsdam (February 2015). All participants gave written, informed consent in accordance with the Declaration of Helsinki.

Participants

Four hundred and thirty-six university students clicked on the link giving access to our survey. Of these 386 (88.5%) went beyond the title page and 305 (69.9%) completed the questionnaire. Forty-nine students did not consent to having their data saved and analyzed on the last page, so the responses of 256 participants (58.7% of those who clicked on the link) were stored for analysis. Twenty-five participants had provided incomplete data (>40% missing responses) and were therefore excluded from the final analyses, so the final sample consisted of data from 231 German-speaking university students of whom 75.8% were women (M age = 23.5 years ± 2.7; range: 18–35 years) and 23.8% were men (M age = 25.4 years ± 3.8; range: 20–40 years). One 24-year-old participant did not provide information about gender.

Experimental Manipulation

When they clicked through to the second page of the online questionnaire participants were randomly assigned to one of the three experimental conditions. Participants in condition A (fivefold overestimation of prevalence; Franke et al., 2011) read the following, "A few months ago a representative study showed that more than 50% of all university students in Germany use caffeine pills in order to enhance cognitive functioning and improve learning." Participants in condition B (i.e., 50% underestimation of prevalence) read that only 5% of students used caffeine pills for NE. Participants in condition C read, "A few months ago a representative study showed that some university students in Germany use caffeine pills to enhance cognitive functioning and improve learning."

Measures and Information

Past Behavior

This indicator was intended to capture participants' historical NE behavior. They were asked four yes-no questions: "Have you ever used caffeine pills to enhance your cognitive performance and improve your learning?," "Have you ever used a caffeinated synthetic drink ('energy drink') to enhance your cognitive performance and improve your learning?," "Have you ever used any other synthetic substance to enhance your cognitive performance and improve your learning?," and "Have you ever drunk a cup of strong coffee or tea to enhance your cognitive performance and improve your learning?" Responses to these four questions were analyzed separately to characterize the sample, but the mean score was used in the main statistical

analyses. McDonald's $\omega_h = 0.52$ that takes into account the dichotomous nature of these heterogeneous set of items indicated adequate general factor saturation.

Subjective Norm

The descriptive facet of this PWM variable was captured using three statements (see Hammer and Vogel, 2013) to which participants responded using a six-point, i.e., forced choice Likert-type scale (1 = "totally disagree" to 6 = "totally agree"): "Peers whose opinions I value use caffeine pills to enhance their cognitive performance and improve their learning," "People who are important to me would use caffeine pills to enhance their cognitive performance and learning if they were in my position," and "People around me have used caffeine pills to enhance their cognitive performance and improve their learning." The mean score for all three statements was used in the statistical analyses. In our sample the internal consistency of this scale was $\alpha = 0.81$.

Attitude

Participants used a seven-point scale to rate use of caffeine pills to enhance cognitive performance and improve learning on five semantic differentials: 'bad–good,' 'unhealthy–healthy,' 'right–wrong,' 'risky–safe,' and 'useless–useful' (see Ajzen, 2006). Higher values represented a more positive attitude toward use of caffeine pills for NE. The mean score from these five items was used for statistical analyses. In our sample the internal consistency of the scale was $\alpha = 0.80$.

User Prototype

Participants were asked to imagine what a typical user of caffeine pills – perhaps a fellow student from their university – might be like (see Gibbons et al., 1998) and use a seven-point scale to describe that person in terms of five semantic differentials 'stupid–smart,' 'unpopular–well-liked,' 'motivated–unmotivated,' 'effective–ineffective,' and 'wrong–right.' The mean score for the scale was used in statistical analyses; higher means indicated greater social acceptability. In our sample the internal consistency of the scale was $\alpha = 0.75$.

Willingness

Participants were asked to read two hypothetical scenarios and rate their willingness to use NE in each (see Gibbons et al., 1998). In scenario one, they read: "Suppose that a friend from your study program has written on Facebook that he recently used caffeine pills from the drugstore to improve his learning." Participants then rated how likely it was that they would take caffeine pills at some point using a six-point, i.e., forced choice Likert-type scale (1 = "very unlikely" to 6 = "very likely"). In scenario two, they read: "Usually you are well prepared for exams, but this time you feel tired and worn out. Although you are trying hard, you just don't seem able to prepare well for the forthcoming exam. You have the option of taking caffeine pills to dispel your fatigue and thus revise more effectively." Participants then responded to two questions ("If you had the opportunity, would you be willing to use caffeine pills?" and "Would you be willing to experiment with caffeine pills under some other circumstance if you had the opportunity to do so?") using a six-point, i.e., forced choice Likert-type scale (1 = "absolutely not willing" to 6 = "perfectly willing." A mean score was calculated and used for statistical analyses, with higher scores indicating greater willingness to use caffeine. In our sample the internal consistency of this scale was $\alpha = 0.88$.

Intention

This variable was measured very simply, by asking participants the single specific question "Do you intend to use caffeine pills for cognitive enhancement and to improve learning in preparation for your next exams?" Responses were given on a six-point, i.e., forced choice Likert-type scale (1 = "definitely not" to 6 = "yes, definitely").

Personal Details

Participants were asked to provide their age and gender, and state whether they were currently enrolled as a university student.

Manipulation Checks

After responding to all the scales described above and providing personal data participants were asked "According to recent research what percentage of university students in Germany have used caffeine pills at least once to enhance their performance and improve their learning?" The response was entered in a free-text input field. Participants were also asked whether they thought there was anything suspicious, wrong, or strange about the questionnaire, and in particular if they thought they had been manipulated by the ways in which we gave or asked for information earlier in the questionnaire.

Debriefing

The last page of the questionnaire provided full information about the goals and procedure for the study. This included a statement of the actual estimated prevalence of use of caffeine pills for NE among university students (i.e., 10%) and an explicit admission that we had tried to deceive our participants about this statistic in two experimental conditions. Participants had to tick response boxes to indicate that they had read and understood this information and consented to the confidential storage and analysis of their data for scientific use by the Division of Sport and Exercise Psychology of the University of Potsdam.

Statistical Analyses

SPSS 22.0 was used to calculate all descriptive statistics and for tests for group differences (ANOVA, MANOVA) and frequency distribution tests (χ^2 test). Structural equation modeling (SEM) with Amos 22.0 was used to determine whether our data were consistent with the PWM. General model fit was evaluated according to established criteria ($RMSEA < 0.08$, $CFI \geq 0.95$, $SRMR < 0.08$; e.g., Hu and Bentler, 1999; Beauducel and Wittmann, 2005) and a Bollen–Stine bootstrap (1000 iterations) was used to estimate confidence intervals for regression weights. A SEM multigroup moderation approach (Byrne, 2010) was used to investigate experimentally induced alterations in the relative predictive power of PWM predictors of willingness and intention (Lowry and Gaskin, 2014). These tests were carried out with a program created by Gaskin (2012) which calculates z-scores based on critical ratio tests of the multigroup model and unstandardized estimates.

The significance level was set at $p < 0.05$ for all analyses. Information from the second question of the manipulation check was evaluated qualitatively.

RESULTS

Randomization Checks

One-way ANOVA revealed no significant age differences between the three groups [$F(2) < 1$], indicating that in this respect the randomization procedure was successful. However, assessment of the gender ratios in the three groups indicated that there were fewer men ($n = 12$) and more women ($n = 73$) than expected in experimental condition B, $\chi^2(2) = 7.82$, $p < 0.05$. Previous research suggests that male and female students may differ in their use of caffeine for NE (Franke et al., 2011), so this randomization error might have resulted in group differences in 'past behavior'; however, in practice there were no significant differences between conditions with regard to either historical use of specific substances (all *p*s *n.s.*; see below) or mean scores used in the statistical analyses (MANOVA results; see below). We therefore concluded that in spite of the randomization error (under-representation of men in condition B) the randomization process was successful overall.

Manipulation Check

The group mean responses to the question about what percentage of university students in Germany used caffeine pills for NE on at least one occasion were as follows: group A (fivefold overestimate of prevalence, i.e., 50%) $M = 50.39\%$ ($SD = 13.24$), group B (50% underestimate of prevalence, i.e., 5%) $M = 11.28\%$ ($SD = 13.88$) and group C (no information about prevalence) $M = 38.18\%$ ($SD = 20.34$). This finding is illustrated in **Figure 1**. There were group differences in responses [univariate ANOVA, $F(2,228) = 130.2$, $p < 0.01$]. The participants' free responses to the second manipulation check question indicated that participants did not see through the experimental manipulation.

Description of Past Behavior

Thirty-one participants (13.4%) reported having used caffeine pills to enhance their performance on at least one occasion. High-dose synthetic caffeinated drinks ('energy drinks') had been used by 39.0% ($n = 90$) and 14.3% ($n = 33$) reported having used some other synthetic substance for NE, whilst 77.1% ($n = 178$) had used a cup of strong coffee or tea, or some other natural substance for NE.

Main Analyses

PWM Model Fit

Descriptive statistics for all variables are summarized in **Table 1**. The value of Mardia's multivariate kurtosis statistic was 1.24, indicating the multivariate normality of our data. The low variance inflation factor of 1.7 suggested that multicollinearity could be dismissed as a possible source of bias.

Structural equation modeling indicated that our data were a good fit with the predictions of the PWM after we had taken into account additional correlations between 'past behavior' and the residual variance in 'intention' ($r = 0.18$, $p < 0.05$) and between 'past behavior' and the residual variance in 'willingness' ($r = 0.30$, $p < 0.01$), $\chi^2(1) = 1.95$, $p = 0.16$; $RMSEA = 0.06$; $CFI = 0.99$, $SRMR = 0.01$. The structural model with regression weights for relationships between variables (bootstrapped *CI*s in **Table 2**) and determination coefficients for variables is displayed in **Figure 2A**.

TABLE 1 | Descriptive statistics for all variables included in SEM.

Variables	*M* (*SD*)	Range	Skewness	Kurtosis
Past behavior	1.36 (0.26)	1–2	0.68	0.12
Attitude	2.88 (1.04)	1–5.80	0.06	−0.23
Subjective norm	2.25 (1.19)	1–6	0.79	−0.47
User prototype	4.34 (0.90)	1–7	−0.09	0.40
Intention	2.13 (1.38)	1–6	1.04	0.08
Willingness	3.00 (1.39)	1–6	0.21	−1.08

N = 231 for all variables.

Regression weights for the association between 'attitude' and 'intention' in the reasoned action pathway and the sequence of associations linking 'past behavior' to 'user prototype' to 'willingness' in the social reaction path were all low (all $\beta_{stand.} \leq 0.10$). 'Willingness' had a substantial effect on 'intention' ($\beta_{stand.} = 0.62$). The model explained 38% of variance in 'willingness' and 61% of variance in 'intention.'

In summary, our main hypothesis, that the PWM can be applied to university students' willingness and intentions with respect to use of caffeine pills for NE, was supported.

Experimental Effects on Variable Means

The MANOVA omnibus test revealed no significant effect of experimental condition on the six PWM variables, $F(12,448) = 0.91$, *n.s.* We therefore concluded that provision of experimentally manipulated information about peer behavior did not produce group mean differences in any of the investigated variables.

Experimental Effects on Regression Paths

Model fit indices remained acceptable for the multigroup estimation model, $\chi^2(3) = 6.85$, $p = 0.08$; $RMSEA = 0.07$; $CFI = 0.99$, $SRMR = 0.01$. Provision of experimentally manipulated evidence about prevalence lowered regression

TABLE 2 | Bootstrapped 95% *CI*s for regression weight ($\beta_{stand.}$).

Parameters			Lower boundary	Upper boundary
Past behavior	→	Subjective norm	0.37	0.58
Past behavior	→	User prototype	−0.08	0.19
Past behavior	→	Attitude	0.34	0.53
Subjective norm	→	Willingness	0.08	0.30
Attitude	→	Willingness	0.28	0.50
User prototype	→	Willingness	−0.06	0.14
Subjective norm	→	Intention	0.01	0.24
Attitude	→	Intention	−0.01	0.21
Willingness	→	Intention	0.51	0.72

N = 231 for all variables.

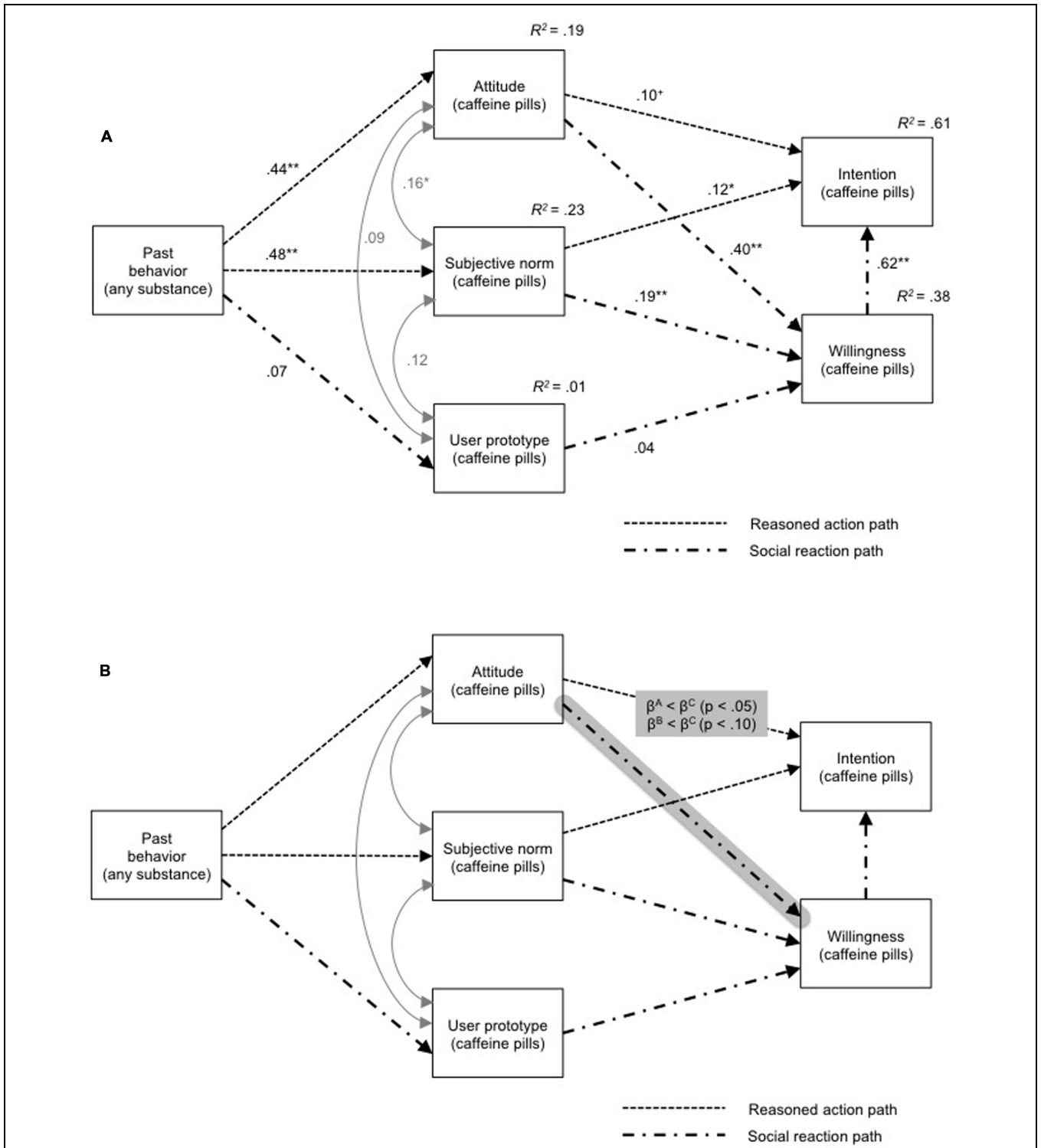

FIGURE 2 | The Prototype Willingness Model (Gibbons et al., 2009) with results from SEM in (A) (R^2 for PWM variables and $\beta_{stand.}$ for paths) and the illustration of experimental effects (B).

weight for the associations between 'attitude' and 'willingness' in condition A by 45% relative to the control group, which did not receive any prevalence information; a similar effect (lowered regression weight by 40%) appeared as a statistical trend in condition B (**Figure 2B**; condition A: $\beta_{stand.} = 0.31$, $p < 0.01$; condition B: $\beta_{stand.} = 0.34$, $p < 0.01$; condition C: $\beta_{stand.} = 0.57$,

$p < 0.01$). This means that in our sample provision of information about prevalence of use of caffeine pills for NE decreased the predictive value of attitude to use of caffeine for NE on willingness to do so.

DISCUSSION

Testing predictions derived from a theory of behavior minimizes the risk of reporting random effects and overestimating relationships; it is thus a suitable strategy for uncovering the psychological mechanisms underlying behavior and behavior change (Zelli et al., 2015). This study showed that the PWM, an established social cognitive theory of behavior, can be used to describe university students' willingness and intention to use caffeine pills to enhance their academic performance (NE). On the basis of this result and previous findings on the effects of peer pressure (Sattler et al., 2013a,b, 2014) we explored whether providing information about the prevalence of a behavior amongst peers – in this case use of caffeine pills for NE – would influence motivational variables and their interrelationships. We found that attitude was a less powerful predictor of willingness to use caffeine pills in experimental condition A, in which participants were informed that recent research indicated that 50% of all university students in Germany used caffeine for NE. There was a trend in the same direction ($p < 0.10$) in condition B, where participants were informed that only 5% of peers used caffeine for NE.

Interestingly, in this investigation attitude was a much weaker predictor of intention than in other investigations of problematic consumption behavior (e.g., $r_+ = 0.62$ in a meta-analysis of intention to consume alcohol, Cooke et al., 2014; $r = 0.55$ in a meta-analysis of athletes' intention to use doping substances, Ntoumanis et al., 2014). The most likely explanation for this is that we chose to measure a very specific intention, i.e., intention to use caffeine, in pill form, in the next exam period. The relatively skewed distribution ($z = 1.04$) of rather low intentions ($M = 2.13 \pm 1.38$ on a six-point Likert scale) corroborates this explanation. Our participants' willingness to use caffeine for NE was somewhat higher ($M = 3.00 \pm 1.39$) and barely skewed ($z = 0.21$). We consider that our very straightforward way of measuring a very specific intention represents a valid, reliable indication of intention with respect to the behavior in question, we therefore argue that the 'willingness' construct is the more interesting proximal psychological predictor of NE (Sattler et al., 2014) and should be investigated further. In particular, we recommend research into the conceptual relationship between willingness and intention (empirical data from many studies based on the PWM suggest that the two constructs are fairly highly correlated, c.f. Todd et al., 2014; $\beta_{stand.} = 0.62$ in our sample). We think that willingness to engage in a given behavior may be much more sensitive to changes in motivational predictors (e.g., in attitude) and to situational factors than an intention to do so. A fundamental assumption of the PWM is that willingness is the basis of socially reactive, i.e., 'spontaneous' or unplanned behavior; this suggests that willingness would be a suitable target for public health interventions.

Structural equation modeling modeling enabled us to estimate correlations between the PWM variable past behavior and the residual variance in willingness and intention with respect to the relevant behavior. In accordance with Wolff and Brand's (2013) behavioral approach to investigating motivation to use NE we measured our participants' past NE behavior without regard for the substances involved although we measured willingness and intention in relation to a specific substance, namely caffeine pills. Our data suggests that an individual's general disposition to use neuroenhancers is a product of unobserved variables in addition to the PWM variables we measured. These unidentified variables have a considerable impact on willingness and intention to use specific neuroenhancers and perhaps NE more generally. Candidates for these thus far unidentified variables might be found in the psychological roots of NE behavior and perhaps in the goals at which NE is directed. More generally we endorse Lazuras's (2015) recommendation, made in relation to research on doping in sport (see Zelli et al., 2015, for parallels between doping and NE), that researchers should develop coherent explanatory models that account for environmental influences, demographic variables, culture, and exposure to information in the media.

The PWM variable past behavior was linked to social norm and attitude but had almost no relationship with user prototype. Participants' images of the "typical user" (Gibbons et al., 2009) of caffeine pills, including social acceptability (i.e., user prototype) also had little impact on willingness to use NE. In the terminology of the PWM the basis for socially reactive use of caffeine pills to improve academic performance seems to be the strong influence of attitude on willingness; user prototype appears to play little role in socially reactive NE in this instance. This may be due to our choice of example neuroenhancer, namely caffeine pills. Caffeine pills may be more likely than other caffeine products such as 'energy drinks' to be treated as a pharmaceutical that should not be taken recklessly, or in response to peer pressure. If we assume that university students are better educated than the general population we might expect them to be more resistant to social influences and generally less prone to unplanned, socially reactive behavior and hence that user prototype would be a stronger predictor of NE behavior in other samples and in relation to other substances.

The experimental manipulation of information about prevalence of use of caffeine for NE amongst peers (rather widespread; rare) did not affect participants' subjective norm for this behavior, in other words quantitative information about prevalence did not appear to be internalized and incorporated into belief systems immediately. This may be because the information given in conditions A (50% prevalence, i.e., a fivefold overstatement of actual estimated prevalence) and B (5%, i.e., half the estimated prevalence) did not correspond with our participants' existing perceptions based on personal observations. The responses of the university students in condition C (no information on peer prevalence) to the manipulation check question about prevalence (see **Figure 1**)

provide some indication of students' pre-existing perceptions of NE prevalence and suggest that such perceptions vary widely. We suggest that receiving new information about peer prevalence might weaken the association between attitude to a given behavior and willingness to engage in it. Our finding that in condition A the predictive power of attitude with respect to willingness decreased by 45% might be taken as an indication that our participants had begun to reflect on their point of view in response to the rather surprising – i.e., inaccurate, experimentally manipulated – information about the prevalence of NE amongst their peer group. This finding reinforces our main contention, shared by other authors (Wolff and Brand, 2013; Wolff et al., 2014; Zelli et al., 2015), which is that social cognitive theories which define relationships between, e.g., attitude and other psychological predictors of behavior (in this case NE) provide valuable insight into the psychological mechanisms underlying behavior change and hence can be used to develop behavior prevention programs.

The limitations of this research should be acknowledged. First of all, psychological theories such as the PWM are intended to predict behavior. We have neither predicted a temporal relationship (e.g., that past behavior influences attitude) nor measured observed behavior (e.g., use of caffeine pills in the next exam period) following an experimental treatment. We experimentally manipulated one variable (information about prevalence) and were thus able to make causal inferences related to this manipulation (providing information about prevalence reduced the influence of attitude to NE on willingness to engage in it). We are, however, unable to draw conclusions about the validity of theoretical assumptions about the causal relationships between other variables (e.g., the direction of the association between subjective norms and willingness; **Figure 1**) as our evidence on this was correlational. Longitudinal studies are needed to draw conclusions about the consequences of changes in motivational determinants. Another limitation of our study is that our analyses were based on data from an *ad hoc* sample of university students which may not have been representative of the population. Although, we are optimistic that our findings are valid further studies are needed to corroborate our findings and interpretation.

CONCLUSION

We hope that future research will be theoretically informed, seeking to address research questions derived from and relevant to psychological theory. By taking this kind of approach we have shown that information about the prevalence of a behavior amongst peers – in this case use of NE to improve academic performance – might have a deterrent effect via attitude to NE and willingness to engage in NE. The approach described in this study might be particularly useful for the designers of public health campaigns.

AUTHOR CONTRIBUTIONS

RB developed this research question. HK conducted the empirical part of the study as a part of her bachelor thesis. RB and HK jointly re-analyzed the data, adjusted and broadened the chain of arguments, and then cooperatively wrote this report.

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