Emotional States, Personality and the Sense of Agency

Determinants of Intentional Binding as a proxy for Dopaminergic States

Inaugural-Dissertation zur Erlangung der Doktorwürde der

Fakultät für Humanwissenschaften der Universität Regensburg,

vorgelegt von

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-2020-

Regensburg, 2020

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Content

Acknowledgements

Throughout these three years, I had lots of support for which I would like to say thank you for:

First, I would like to say thank you to my supervisor Petra Jansen without whom I would never have started (not even to mention completed) my PhD in the first place. Your persistence in talking me into it opened a whole new career path for me and I can't express in words, how grateful I am for you believing in me as you did. You gave me an incredible freedom in choice of topic and work management but have guided me with innovative ideas and constant support at the same time all the way. Your expertise was invaluable in shaping the research questions, methodology and analyses. And your drive for efficiency pushed me when I needed it the most and brought me where I am today!

Second, I would like to acknowledge Hedwig Eisenbarth who gave me the opportunity to be part of her Lab and made me feel at home at the other end of the world. You challenged me to acquire skills that meet the Zeitgeist and have awaked an enthusiasm for science in me that I did not know I had. I sincerely hope we will continue to work together for a bit longer.

I would also like to thank my friends and colleagues, especially Melina Albrecht, Marion Duerrwanger, Marlene Bollmann, Katrin Sonntag, Franziska Werschmann, Franziska Schroter, Clara Scheer, Jeremy Meier and Jakob Scotts-Bahle, who were always there for me either as a wise counsel, a sympathetic ear or just happy distractions. I'm so grateful to have you!

Finally, I would like to thank my parents Irmi and Heini and my favourite brother Jan for being my safety net but also my critical instance throughout this entire process. I would not have handled it the same way, earthed and with a bit of relativism (but not without expectation), if it wasn't for what we have experienced as a family in the last 15 years and what I have learned from the three of you.

Summary

We are inclined to trust our feeling of control or sense of agency although it results from our subjective perception and construction of the world—hence, it can be inaccurate (Moore, 2016). Sense of agency serves central social functions such as the attribution of social or legal responsibility (Haggard, 2017; Haggard & Tsakiris, 2009; Moore, 2016), but how can we gauge under which circumstances we can rely on our sense of agency?

The goal of this thesis was to understand what factors bias and impact our feeling of control as these findings have implications for the extent of legal culpability and criminal sentencing. Specifically, we focused on factors in personality that have been found to increase risk of criminal behaviour and emotional states that have shown varying effects on other cognitive and perceptual processes. The previously postulated dopamine hypothesis (Aarts et al., 2012; Graham et al., 2015; Moore et al., 2010) served as an underlying rationale throughout. Sense of agency was measured with an implicit paradigm called intentional binding (Haggard et al., 2002), referring to the subjective compression of the time between a self-initiated action and its perceived outcome (Haggard et al., 2002).

In the first study, we measured interindividual differences in personality and substance use history as a proxy for low dopaminergic states and found reduced intentional binding in substance users and individuals with higher vulnerable narcissism—preliminary evidence for the dopamine hypothesis (Render & Jansen, 2019).

In the second study (Render & Jansen, 2020), a state of sexual arousal was induced, which has previously been found to be associated with a high dopaminergic activity, and its influence on the intentional binding components—action binding and outcome binding—was analysed. Action binding represents the feeling of control in action performance. Outcome binding displays how much actions are linked to the consequences; it detects the level of awareness of consequences. No specific effects of sexual arousal were observed in the second study, but unspecific general arousal

was associated with impaired action binding while outcome binding remained intact. These results rejected a linear relationship between intentional binding and dopamine potentially suggesting an inverted U-function. The results also indicated that action binding is more closely connected to the dopaminergic system than outcome binding (Tanaka et al., 2019).

Finally, by merging the designs of the first two studies in the third study (Render et al., under review), we partially replicated, and expanded upon the previous results: We investigated the interactional effects of the emotional states (sexual arousal and pleasure) and personality traits. In addition to subjective ratings, manipulation check for arousal induction was performed and partially confirmed in pupil dilation, skin conductance and heart rate on a physiological level. Dopaminergic activity was indexed via spontaneous eye blink rates. Findings of this third study revealed that sexual arousal specifically impaired both binding components but results for action binding were more pronounced, underscored by effects of blink rates. Personality traits interacted with the response to emotional states showing that individuals with higher vulnerable narcissism had reduced action and outcome binding in sexual arousal and reduced outcome binding in pleasure. Higher anxiety showed reduced action binding and increased outcome binding in all emotional states. Higher psychopathy was associated with intact action binding in sexual arousal but reduced outcome binding in sexual arousal and pleasure. Individuals reporting more substance use history, showed increased action and outcome binding when sexually aroused as well as increased outcome binding in pleasure.

Our results underline the importance of personality for the feeling of control in highly emotional states. Sexual arousal impairs the feeling of control over actions and individuals scoring high on vulnerable narcissism seemed to be more vulnerable to show a reduced feeling of agency in emotional states. In contrast, people reporting high substance use history and individuals scoring higher on psychopathy and lower on trait anxiety seemed to be more resilient to that. The latter also showed a reduction in the feeling of control over consequences which did not occur in other participants indicating a psychological distancing moment from the action outcome. The

interaction between constant interindividual differences based on personality traits and temporary intraindividual adjustments induced by emotional states in the feeling of control bridges the gap between these research fields showing a more holistic picture of our feeling of control under different circumstances. Variance in feeling of control in emotional states is important for evaluations of criminal responsibility. If the feeling of control is reduced, this could result in limitations of responsibility—total or partial exemption from criminal liability—for psychological and psychiatric expert reports regarding compulsory admission and treatment.

1. Preface

When we act voluntary, we do not to feel as though actions simply happen to us, we tend to feel as though we are in charge. The sense of agency refers to this feeling of being in the driving seat when acting. However, as with other aspects of conscious experience, this perception is not a one-to-one reproduction of the reality in an objective sense. In other words, our experience of agency can be flawed. Even though we tend to feel immune to such cognitive failures, we are almost certainly mistaken trusting our beliefs at some point (Moore, 2016). The buttons at pedestrian crossings for example create the illusion of us being able to make the light go green. However, many of these buttons are in fact not doing anything, instead a timer is being used to regulate the traffic lights (McRaney, 2013). Intriguingly, most of us fail to notice the lack of a causal linkage between our button press and the green light. But what is so fascinating about these lapses in our sense of agency? First, it reminds us, that the accuracy of this experience is not a given. Our brain is constantly constructing the sense of agency, using predictive and postdictive external and internal signals that can lead to a false interpretation of the reality. Second, these lapses reveal something quite remarkable about our sense of agency: its impressive flexibility (Moore, 2016). Extensive research has explored determinants that challenge our sense of agency's flexibility. It can depend on personality as trait-like interindividual differences and it can vary depending on negative emotional states, requiring us to adjust our sense of agency temporarily.

It is not fully understood what underlying mechanism exactly make our sense of agency so flexible yet, but several researchers in this field have suggested that the accessibility of dopamine might be able to explain inter- and intraindividual differences in the binding strength between actions and consequences. Still, operationalisations of the dopamine hypothesis have not been met. Drawing attention to the field in which sense of agency is considered crucial for an individual's outcome—criminality—we were led by the following questions: Do we differ systematically in our sense of agency according to our personality traits? Is the sense of agency impaired in negative states only, or do ambivalent or positive states have the same influence? And does the response to emotional states interact with individual characteristics that are linked to variations in anxiety or arousal reactivity?

This thesis attempts to get a step closer to understand the link between the sense of agency and the dopaminergic system, how flexible the sense of agency really is, and what circumstances may impair our sense of agency.

2. Theoretical Background and State of Research

We are agents—engaging in actions and perceiving the outcomes—which makes us realise that we are changing the world around us. This experience of having the capacity to bring change into the world is called the sense of agency. A key challenge of the sense of agency research is the discovery and evaluation of measures, particularly implicit measures, as a divergence between explicit and implicit measures has been reported (e.g. Dewey & Knoblich, 2014). One approach to capture the sense of agency implicitly is via intentional binding, a measure that has received considerable interest and has been used extensively in research (Moore & Obhi, 2012).

2.1 Sense of Agency

Usually, we feel as though we are in control of what we do, at least more often than we don't—this means our feeling of control is intact—even if the degree of consciousness for our actions and action outcomes varies. The term 'sense of agency' refers to this experience of controlling one's own actions, and, through these actions, events in the outside world (Haggard & Chambon, 2012). Sense of agency is also defined by naming the cause of action (Gallagher, 2000), it is essential to explain changes in the external world and a foundation for one's future predictions (Wen et al., 2015). This knowledge, to be the cause of one's own action, is an elementary and constant root for the interaction with the world (Synofzik et al., 2013).

But why is sense of agency important? A substantial amount of mental illnesses, such as psychotic episodes, involve abnormalities of agency in which actions feel as though they were not their own and feel imposed by some other agent. Another example is depression as it goes along with the experience of helplessness and loss of agency. However, sense of agency is not only relevant in clinical settings. Focus of this work is, that it also plays part in the foundation for our society more generally: the idea that we are responsible for our own actions is built on the assumption that we have a sense of control for our actions and that we are aware of the consequences (Haggard & Chambon, 2012). In Germany, this is even rooted within the law requiring a person to be legally culpable if they are to be found guilty of a crime (§20 Schuldunfähigkeit wegen seelischer Störungen, §21 verminderte Schuldfähigkeit StGB).

In order to understand how sense of agency arises, two neurocognitive origin models, the prediction model and the retrospective inference model have been proposed, investigated and widely discussed (Hughes et al., 2013; Moore & Obhi, 2012; Tanaka et al., 2019). The predictive model suggests that the sense of agency is generated by processes associated with control of voluntary action. Predictions about future states of the motor system and about sensory consequences of movement are needed for efficient motor control and learning (Wolpert & Ghahramani, 2000). The internal forward model provides these predictions in two different classes: forward dynamic, capturing the dynamics of bodily movement, and forward sensory, capturing the causal relation between movements and their sensory consequences. According to the 'comparator model' (Blakemore et al., 2002) of the sense of agency, the forward sensory model generates predictions of likely sensory consequences of movements based on an efference copy of motor commands. A predicted state is generated from an efference copy of one's motor command and is compared with an approximate actual state. A match between predicted and actual sensory consequences of movement produces the sense of agency, whereas a mismatch implies that the effect could have potentially been produced by others (Blakemore et al., 2002).

The second model explaining the sense of agency origin is the retrospective inference model minimizing the specific contribution of the motor system to generate the sense of agency. To generate the sense of agency by retrospective inference, we use sensory information producing the causal origins of an action and its consequences. According to the 'theory of apparent mental causation' (Wegner & Wheatley, 1999), three conditions have to be met to promote the sense of agency: a thought or intention that, first, occurs prior to action, second, is consistent with the action, and third, is the most plausible cause of the action. By evaluating studies that operationalise these two different models, it has been concluded that both, prediction and retrospective inference, contribute to sense of agency (Moore & Obhi, 2012). Sense of agency can be measured implicitly via intentional binding (also called temporal binding) and sensory attenuation (Dewey & Knoblich, 2014). Both measures presuppose that we perceive self-initiated actions and their outcomes differently than ones that were involuntary or that were performed by other's.

2.2 Sensory Attenuation

Sensory attenuation builds on the assumption that self-initiated action-effects are perceived less intense subjectively, e.g. less loud, than actions caused by others or machines (Sato, 2008; Weiss et al., 2011). This effect can also be seen on a neurological level, in reduced auditory sensory-perceptual processing (N1 component) for self-initiated actions (Baess et al., 2009). However, the link between sensory attenuation and the sense of agency is still preliminary as the necessary preconditions are controversy (Dewey & Knoblich, 2014). Therefore, most of these studies investigating the underlying processes of sense of agency rely on an implicit paradigm called 'intentional binding'.

2.3 Intentional Binding

Measuring sense of agency via intentional binding presupposes that when an action is intentional and feels controlled by the actor, a binding effect can be observed: the time between action and event is perceived as shorter than it really is; in other words, there is a subjective compression of time between an action and its outcome (Haggard et al., 2002).

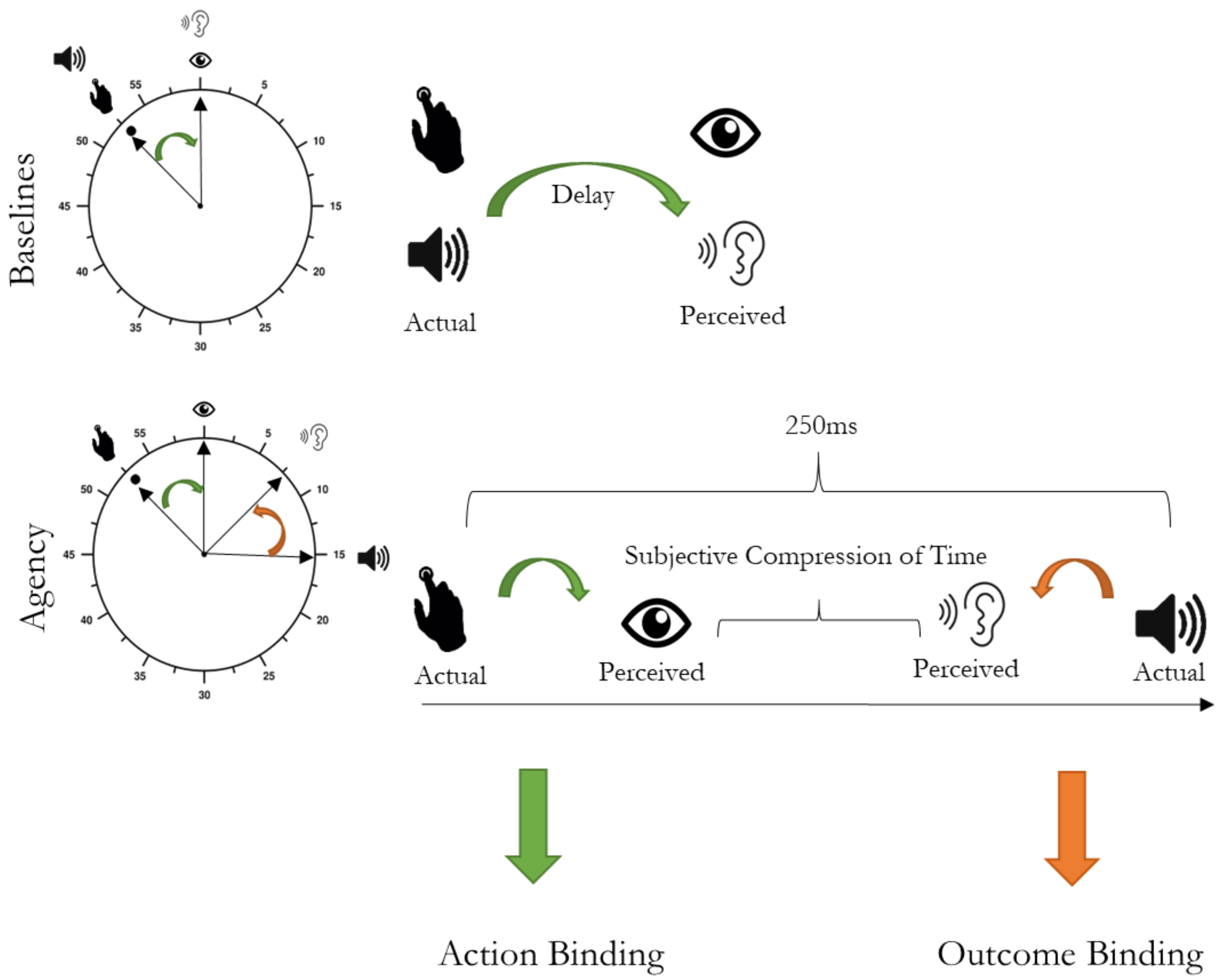
Intentional binding can be quantified with different tasks, such as the Libet clock and the interval estimation (also interval reproduction) task. In the Libet clock task, participants report the onset time of certain events, which can either be voluntary performed actions (e.g. key presses) or sensory outcomes (e.g. presentation of tones) via the position of a clock hand. Dependent on the condition, events can occur in isolation (baseline condition) or action and outcome can occur in the same trial (operant condition) separated by a short interval (e.g. 250ms). Temporal binding is measured through the time estimation error of actions and outcomes in comparison to the baseline trials. In voluntary actions, two perceptual shifts can be observed indicating an attraction of action and outcome: actions that caused a sensory outcome were experienced later and outcomes were experienced earlier in the operant conditions, as compared to events in the baseline condition. This effect is unique for voluntary actions; reversed effects were shown for involuntary movements: When an action was induced via transcranial magnetic stimulation over the primary motor cortex, participants perceived the onset of their action earlier and the onset of the tone later than in the baseline condition (Haggard et al., 2002; Tanaka et al., 2019).

While time estimations for actions and outcomes in the Libet task are made with visual reference—an analogue clock rotating faster than usual—the interval estimation task is constructed without such a visual reference. Time estimations are performed by reproductions of the subjective length of a previously experienced event: after hearing two tones separated by different intervals, participants are asked to reproduce the length of the tone by pressing a key for the estimated time of the interval. In the passive condition, both tones are generated by the computer, in the active condition, the first tone is caused by a key press of the participant. Temporal binding occurs in the active conditions only (Dewey & Knoblich, 2014; Poonian & Cunnington, 2013). Although temporal binding effects revealed by interval reproduction are presumed to be driven by the perception of a causal relationship between two events, it does not necessarily involve intentionality or agency. The Libet clock method in contrast allows to differentiate between shifts in the perceived time of actions and their effects, the so-called event boundaries (Dewey & Knoblich, 2014). Shifts in event boundaries could occur independently of changes in the representation of the temporal interval separating the two events (Humphreys & Buehner, 2010). By relying on event boundaries rather than the temporal intervals per se, the Libet Clock task is possibly better suited to modulate self-agency than the interval estimation task. Evidence for this can be found in a meta-analysis showing larger effect sizes task for the Libet Clock task compared to the interval estimation procedure casting doubts of the validity to detect subtle differences in binding derived from the manipulation of sensorimotor parameters in the interval estimation task (Tanaka et al., 2019).

In the Libet Clock task, temporal binding is indicated by a forward shift in the judged time of an action toward its outcome (action binding) and the backward shift of an outcome toward a causal action (outcome binding) (Lush et al., 2019) (Figure 1). These components of intentional binding—action and outcome binding—are driven by distinct underlying mechanisms and should therefore be considered separately (Tanaka et al., 2019; Wolpe et al., 2013; Wolpe & Rowe, 2014).

Figure 1

Intentional binding paradigm. Finger = key press, eye = perceived time of key press, speaker = tone, ear = perceived time of tone.



2.3.1 Components of Intentional Binding

As such, action and outcome binding have more frequently been interpreted as two separate cues for time estimations in recent research (Christensen et al., 2019; Saito et al., 2017; Tanaka et al., 2019; Wolpe et al., 2013). Thus, it is more informative, as the behavioural pattern of each binding component can provide insight into the processes regulating them (Tanaka et al., 2019; Wolpe & Rowe, 2014). Understanding these underlying processes of intentional binding may contribute to comprehend the mechanisms underpinning abnormal experience of agency. As yet it is presumed that action binding—the perceptual attraction of a voluntary action towards its outcome—is more dependent on a sense of control of outcome onsets with voluntary actions (Tanaka et al., 2019), as it is built on the learned action-effect association (Moore & Haggard, 2008). Outcome binding—the perceptual attraction of an outcome towards a voluntary action—whereas, depends more on the degree to which participants can predict, rather than control, the action outcome onsets (Tanaka et al., 2019), as it relies on a pre-activation mechanism (Waszak et al., 2012). But what factors determine our ability to predict and control actions?

2.4 Dopamine Hypothesis

A physiological determinant for our feeling of control that several researchers have postulated is the accessibility or activity of dopamine (Aarts et al., 2012; Graham et al., 2015; Moore et al., 2010). The manner of relationship between the dopaminergic system and intentional control has not yet been understood. Dopamine is involved in responses to attention-inducing stimuli and reward-related stimuli (Schultz & Dickinson, 2000). It is part of the motivational reward system (Berridge, 2007; Wittmann et al., 2005), involved in memory formation, motoric functions (Volkow et al., 1998) and regulates the prediction of errors in action results (Schultz & Dickinson, 2000) and executive control (Aston-Jones & Cohen, 2005).

Building on this assumption—reward and positive affect playing an important role in the control of voluntary action—one study tested the effects of pictures with positive valence via priming and found enhanced intentional binding by modulating dopamine functioning (Aarts et al., 2012). This positive priming effect was more pronounced in participants with higher dopaminergic activity, i.e. indicated by higher blink rates. The authors suggest an involvement of striatal dopamine activity in the evaluation process of oneself as an active agent in reward-related information. Thus, the activity of dopamine could increase the temporal binding of action and event through higher action coherence and self-causation, hence a higher sense of agency. According to this theory, individuals with a low dopamine level will not profit from reward signals in their sense of agency (Aarts et al., 2012).

An involvement of the dopaminergic system in intentional binding has also been found for schizophrenia (Haggard et al., 2003; Hauser et al., 2011; Hur et al., 2014; Voss et al., 2010), schizotypy (Asai & Tanno, 2008), psychosis-like experiences and age (Graham et al., 2015), as well as ketamine as a model for psychosis (Moore et al., 2011). It has been suggested that altered action binding indicates deficits in the dopaminergic system involved in action execution (Tanaka & Kawabata, 2019). Since associative learning is strongly influenced by dopamine (Arias-Carrión & Pöppel, 2007; Schultz et al., 1997; Schultz, 2002) and action binding is generated from learned action-effect associations (Moore & Haggard, 2008), changes in action binding are more likely to depend on dopamine changes than in outcome binding. Effects on action binding have been reported for Parkinson patients with dopaminergic medication (Moore et al., 2010; Saito et al., 2017), in testosterone administration (as testosterone induces dopamine release) (van der Westhuizen et al., 2017), for general arousal (Wen et al., 2015), and for negative arousal states such as fear and anger (Christensen et al., 2019)—states that all interact with dopaminergic circuits (Chester et al., 2016; Cho et al., 2017; Fadok et al., 2009). According to this, emotional states can lead to short-term adaptations emphasising the flexibility of our sense of agency intraindividually: The state of control of an individual has been shown to be determined by their emotional state during the performance of actions (Christensen et al., 2019) as a function of arousal and valence of the emotional state.

2.5 Intraindividual Differences: Emotional States

But why does it matter whether sense of agency is responsive to emotional states? Driven by different aims, two studies have been conducted inducing high arousing emotional states and have thus built the foundation for our work.

One reason to induce high unspecific arousal as a part of attention was to examine which underlying processes were involved in intentional binding. It was argued, that attention is defined as an implicit process contributing to the integration of individual features into one object in visual perception (Treisman & Gelade, 1980), hence when manipulating arousal, external cues would not be provided, and the reconstructive processes involved in intentional binding would remain unaffected. If intentional binding would be increased nonetheless, arousal would have enhanced prospective processes confirming that reconstructive *and* prospective processes are involved in intentional binding.

Another aim to test the effect of arousal on sense of agency was to simulate situations in court dealing with loss of control in legal defence. Therefore, the influence of negative arousing states on intentional binding was examined. It was argued, that fear and anger are assumed to attenuate the responsibility over one's own actions, although the effects of negative aroused states on sense of agency had not been investigated until then. The defendant's emotional state prior to and during the action performance is more likely to be considered for the sentence than the emotional quality of the outcome, therefore, it was tested whether negative emotional states would reduce action binding. A possible inference for this reduction is a psychological distancing from outcomes since they are linked to a negative valence.

Along with fear and anger, sexual arousal is categorised as a hot emotion. Hot emotions are direct visceral reactions to risk and can inhibit our rational thinking and the ability to act intentionally (van Gelder, 2013). Hence, sexual arousal exerts a strong influence on our behaviour which may result in criminal behaviour (Ariely & Loewenstein, 2006) and can lead to psychological distancing from action outcomes. Normally, cues of non-consent should inhibit sexual arousal, but sometimes this inhibition process is interrupted or has not even been acquired (W. L. Marshall et al., 1990). This stimulus inhibition theory points out that emotional states, such as sexual arousal and pleasure, can co-occur with the offense, making these states as important for agency research as negative emotional states. Positive moods such as happiness and pleasure have been suggested to facilitate underestimation of risks and engagement in reckless activities like speeding or sexual harassment (van Gelder, 2013). More attention should therefore be drawn to positive and ambiguous arousing states.

Previous studies focusing on the valence of the consequences rather than the state of action shows that the effect of equally arousing emotional stimuli on sense of agency also depends on their valence: Studies using financial incentives or emotional sounds as action outcomes, revealed that negative outcomes reduced intentional binding relative to neutral outcomes. Yet, enhancing effects of positive outcomes on intentional binding were neglectable relative to neutral outcomes (Gentsch & Synofzik, 2014; Takahata et al., 2012; Yoshie & Haggard, 2013). In these studies, arousal cannot explain such valence-dependent effects since positive and negative stimuli were rated as equally arousing. Looking at the effect of valence in low arousing states could therefore be the key to understand the effects of valence separated from high arousal. As emotional states are often treated as two-dimensional—with one being arousal and one being valence (Barrett, 1998)—separating the state of art by these two dimensions could clarify to what extent each of them has an effect on sense of agency.

2.5.1 High Arousal

2.5.1.1 Neutral Valence

In one of the two studies, the influence of emotionally neutral arousal on intentional binding (overall binding) has been operationalised using movement and colours (Wen et al., 2015). Three squares (a = 60-mm) appeared on a screen, with the central one differing in colour. The external squares moved upwards with a speed of 18 mm/s, one at a time at random intervals to avoid a ceiling effect of agency ratings. As soon as participants pressed the space key, the central square started to move. Arousal was induced by the colour of the central square, being either red or black. In this specific type of interval-estimation task, participants estimated the length of the interval between the act of pressing the space key and the central square jumping event. For explicit agency, participants rated the extent to which they felt their action caused the central square to jump on a 9-point scale (1 = not at all to 9 = a lot). It was found that higher arousal induced by the red jumping squares enhanced the implicit binding process between the action and outcome. However, a higher state of arousal had no influence on subjective agency ratings (explicit agency). The results confirmed a stronger intentional binding (*overall* binding) in the arousal condition compared to the neutral condition and importantly, this enhancement was not evoked only by changes in time perception. These findings emphasize that subjective judgment through self-reports and the intentional binding effect seem to reflect different facets of the construct sense of agency (Dewey & Knoblich, 2014; Moore et al., 2012). Wen et al. therefore suggested that the intentional binding effect involves predictive and inferential processes; assuming that arousal only enhances the predictive process. It must be noted that the arousal manipulation was only tested in a second experiment with 10 different participants, whereas no information about arousal check was provided for the participants in the actual intentional binding experiment, limiting the interpretation of results.

2.5.1.2 Negative Valence

These results were extended for emotionally negative arousing states (Christensen et al., 2019)—fear and anger—on action binding. Action binding is specific to conditions, in which an action is internally generated and executed voluntarily (Borhani et al., 2017). In this sense, action binding provides a direct measure showing how close the mental representation of an action is linked to the action's outcome (Christensen et al., 2019). Thus, in this experiment, fear was induced by moderately painful shocks and anger was generated by a frustration task, in which successful performance on the assignment was impossible. The negative emotion reflected the participant's emotional state at the time of acting and was not linked to any specific events in the action binding trials. In both emotional states, the impact of fear and anger reduced action binding.

2.5.1.3 Ambiguous Valence

Sexual arousal can be considered as a state on the upper end of the arousal dimension and has been defined as rewarding (Brom et al., 2014) by stimulating dopaminergic pathways within different brain areas increasing concentrations of dopamine (Damsma et al., 1992; Giuliano & Allard, 2001; Karama et al., 2002; Oei et al., 2012; Ponseti et al., 2006; Rupp & Wallen, 2008; Stoléru et al., 1999). Research focusing on the constitution of sexual arousal in a laboratory setting however, has indicated that it not only overlaps with many positive emotions, but also with negative emotions (Everaerd & Kirst, 1989) such as anxiety and anger (Barclay, 1969; Barlow et al., 1983; Beck et al., 1987; Wolchik et al., 1980). Psychophysiological studies confirmed this ambivalence of the sexual response: high levels of subjective sexual arousal and desire consistently co-occurred with ambivalent affect (e.g. Peterson & Janssen, 2007) which bears upon the influence on perception and cognition. There is a body of research examining the negative effects of sexual arousal on other cognitive processes such as perception (Most et al., 2007) or memory (Mather & Sutherland, 2011). Pleasant erotic distractors have been proclaimed to elicit a temporary emotion-induced blindness in perceptual processes. Thus, erotic stimuli have been revealed to be distracting and cannot be ignored confirming that a deficit in perceptive processing can be evoked by positively arousing stimuli to the same extent as by aversive stimuli (Most et al., 2007). Moreover, regardless of the valence, arousing stimuli, such as erotica and mutilation, affect attentional selectivity measured in binocular rivalry (Sheth & Pham, 2008), in attentional blink (Keil & Ihssen, 2004) and event related potentials (Schupp et al., 2007). It has also been shown that experiencing lower inhibitions in sexual arousal affects predictions of the individual's own judgments, decision-making processes and behaviour, self-control and sexual self-restraint (Ariely & Loewenstein, 2006; Ditto et al., 2006; Skakoon-Sparling et al., 2016; Skakoon-Sparling & Cramer, 2016)—processes that are likely to share mechanisms with intentional binding. However, no research has been conducted to investigate the effect of sexual arousal on the sense of agency yet.

2.5.2 Low Arousal

2.5.2.1 Negative Valence

As a state on the lower end of the arousal dimension, previous research reports a facilitation effect of sadness to some extent but not generally for all cognitive processes (Chepenik et al., 2007). Others claim broader benefits of negative affect for cognition, emotion, and interpersonal behaviour (Forgas, 2014). In terms of control, sadness has shown to induce an inhibiting effect on aggression, aggression control seems to be higher in sad states (Lutz & Krahé, 2018). Studies have reported that dopamine release is increased in certain parts of the brain (the dorsal striatum: caudate and putamen) during processing of self-generated negative emotion of sadness (Damasio et al., 2000) and transiently elicited sadness (George et al., 1995). However, no studies have, to the best of our knowledge, investigated the relationship of sadness and sense of agency yet.

2.5.2.2 Positive Valence

In terms of positive valence, it has frequently been found that calm positive affect (positive valence) broadens cognition, promotes creative problem-solving, improves cognitive flexibility (for a review see Chiew & Braver, 2011), enhances working memory in controlled processing (Yang et al., 2013), increases awareness of intention to act (Rigoni et al., 2015) and facilitate the attribution of self-causation to behaviour (Deci & Ryan, 1985; D. T. Miller & Ross, 1975). First results for increased intentional binding have been reported for priming with positive pictures, indicating dopaminergic modulations (Aarts et al., 2012). A body of research has suggested that dopamine might, at least partially, account for the influence of positive affect on cognition. The dopaminergic theory of positive affect proposes that the effects of positive emotion are specifically linked to increased dopamine release (Ashby et al., 1999). An increased dopamine release can facilitate the ability to initiate a switch among goals and cognitive sets (Dreisbach & Goschke, 2004). A dopaminergic involvement of positive affect has also been suggested for regulation of stability-flexibility balance in cognitive control (Dreisbach, 2006; Dreisbach & Goschke, 2004).

While emotional states challenge our sense of agency to adjust temporarily for a limited amount of time, interindividual differences in substance use history and personality traits could mirror alterations that are assumed to be more long-termed. It could be elucidating to extent this stream of research—sense of agency and legal culpability: simulating situations in court dealing with loss of control in legal defence—to risk factors for criminal behaviour: narcissism, psychopathy, low trait anxiety and substance use history.

2.6 Interindividual Differences: Substance Use History and Personality

Personality is defined as biologically based basic tendency (McCrae et al., 2000) to think, behave and feel in a particular way, consistent and stable over time and situations (Caspi, 1998; Eisenberg et al., 2000; Hertzog & Nesselroade, 1987). Regulatory mechanisms in behaviour and feelings and the underlying motives of the personality traits are likely to contribute to these alterations in agency. Personality traits are thus potential determinants for the sense of agency. However, the term biological based highlights that the dopamine hypothesis potentially accounts for these interindividual differences to some extent as well.

Studies including dopaminergic medication (Moore et al., 2010; Saito et al., 2017) or ketamine (Moore et al., 2011) indicate the relevance of dopamine in substances for intentional binding. Already 20 years ago researchers suspected that chronic use of drugs could induce changes in the neurotransmitter systems, particularly the dopamine system (Koob & Le Moal, 1997). Hence, it is important to investigate whether alterations in the dopaminergic system, caused by drug use, lead to differences in intentional binding. In line with the dopamine hypothesis, these determinants in personality traits and substance use can be singled out as potential equivalents for altered dopaminergic states.

2.6.1 Personality, Substance Use History and Dopamine

Different dopaminergic long-term effects have been reported for the substances cannabis, MDMA (e.g. ecstasy), cocaine, amphetamine (e.g. speed), and psychedelics (ketamine, LSD, and mushrooms).

Generally, use of cannabis, contrary to use of other substances, is not associated with striatal dopamine alterations. However, observable alterations such as lower dopamine release in the associative striatum have been found in users who started early or reported a long duration of usage. Thus, it is difficult to distinguish the effects of chronicity versus use onset (Urban et al., 2012). Ecstasy (MDMA, MDEA, MDA), an activating and hallucinogenic substance, directly affects the neurotransmitter metabolism. In animal trials, an increase of serotonin level in the synaptic cleft was observed, interacting with the dopamine systems causing higher dopamine release (Battaglia et al., 1988). In apes, high doses changed the serotonin system irreversibly, mostly affecting parts of the brain responsible for memory processes and development of anxiety (Ricaurte et al., 1992). Several other studies have confirmed that the level of dopamine receptor availability is lower than normal in drug-addicted subjects (alcoholics, cocaine abusers, crystal abusers, heroin abusers) (Volkow et al., 1990). Cocaine use results in long-term reduction in the dopamine metabolism (Karcum et al., 1990). Even a single cocaine exposure in mice led to alterations in the dopamine metabolism: 10 days after administration, receptors of dopamine cells were still blocked (Ungless et al., 2001). Studies in rats administrating amphetamine suggested a long-term dopamine depletion by destroying dopamine nerve fibres (Ricaurte et al., 1984), and even a single exposure to amphetamine seems to be sufficient to induce long-term behavioural, neurochemical, and neuroendocrine sensitization (Vanderschuren et al., 1999). Regarding psychedelics, ketamine is used in human and animal medicine as an injectable anaesthetic influencing the dopaminergic functions and is often used as a model for delusion and psychosis (Narendran et al., 2005). The dopaminergic receptor availability has been shown significantly up-regulated in chronic ketamine users as a compensation effect for dopamine depletion. This suggests that the repeated use of ketamine for recreational purposes affects the dopaminergic transmission so that potentially less dopamine is available in ketamine users (Narendran et al., 2005). LSD in contrast is known to take effect in two phases, with the later temporal phase mediated by the dopamine receptor stimulation (Marona-Lewicka et al., 2005). Even a single dose of LSD increases the expression of a small set of genes in the part of the brain that is involved in a wide array of cellular functions reflecting the beginnings of long-term neuro-adaptive processes (Nichols, 2002).

While these studies suggest that changes in the dopaminergic system are environmentally caused by substance use, alterations linked to personality might result from interaction of nature and nurture. The definition's term for personality to be 'biologically based' highlights that our body is, to some extent, regulating our cognition, feelings and behaviour. One biological factor that has been postulated to influence our personality is the dopaminergic activity (Depue & Collins, 1999; Fischer et al., 2018).

Respecting narcissism, a recently published study (Miles et al., 2019) has linked the two subtypes of narcissism (Wink, 1991) to the 'Reinforcement Sensitivity Theory' (Gray, 1970). According to this theory, personality has a biological basis connecting neural and behavioural processes in two brain systems: the 'Behavioural Approach System', which regulates the sensitivity to reward, i.e. in motivation, and the 'Behavioural Inhibition System', which regulates the sensitivity to punishment, i.e. in avoidance (Carver & White, 1994). According to this study, an active behavioural approach system and a passive behavioural avoidance system predicted grandiose narcissism, whereas a moderately active behavioural approach system and an active behavioural avoidance system predicted vulnerable narcissism (Miles et al., 2019). A strong imbalance in these systems, such as in narcissism, can be predicted by dopamine levels (Tomer et al., 2014). Psychopathy has been linked to a hyper-active dopaminergic system (Buckholtz et al., 2010) and two dopamine receptor genes have been proven to predict psychopathic personality traits (Wu & Barnes, 2013). Higher dopamine release in several brain areas in individuals with lower trait anxiety has been found in studies combining fMRI and PET supporting the hypodopaminergic models of anxiety (Berry et al., 2019). Dopamine is furthermore assumed to play a role in the regulation of anxiety in healthy subjects (Laakso et al., 2003). Alterations in agency are likely to be found in other personality traits as well, but narcissism, low trait anxiety and psychopathy are being key ones for antisocial behaviour and hence legal responsibility or culpability—a rational that goes beyond the dopamine hypothesis.

2.6.2 Personality, Substance Use History and Agency

Agency is considered to be crucial for morally driven behaviour to seek meaning and to direct actions to reasons (Ward & Gannon, 2006). Substance use history, narcissism, low trait anxiety and psychopathy have been outlined as key risk factors for criminal behaviour (Bowman, 2016; Köhler et al., 2009; Leue et al., 2004): Substance use is a predictor for offending behaviour (Flexon et al., 2016). Narcissism is a predictor for acceptance of violent behaviour (Blinkhorn et al., 2016) and offending (Blinkhorn et al., 2019), and the association between low trait anxiety, psychopathic traits and criminal offending have been widely investigated showing a higher number and greater diversity of crimes, and more violent crimes (Kosson et al., 1990). Treatment is known to be less successful (Ogloff et al., 1990), and it is strong predictor of criminal recidivism (Laurell & Dåderman, 2005).

Substance use history has been outlined to be associated with low self-control (Flexon et al., 2016; Ford & Blumenstein, 2013). A longitudinal study shows that the rate of increase in substance use was higher among participants who had poorer self-control and lower among participants who had better self-control (Wills & Stoolmiller, 2002). However, the relation of implicit control processes such as intentional binding and substance use history remains in the dark.

There are many long-standing statements about the relationship between narcissism and agency suggesting different views (Dimaggio & Lysaker, 2015). One study using the Libet clock task to measure intentional binding and the narcissistic personality inventory (NPI) to capture narcissistic traits stated participants with high and moderate narcissism to have stronger outcome binding, whereas participants with low narcissism had reduced outcome binding (Hascalovitz & Obhi, 2015). The authors argued that narcissistic people perceive themselves and their actions as particularly important and unique, experience themselves as highly effective agents, are more motivated and act more dominant and show therefore stronger outcome binding (Hascalovitz & Obhi, 2015). On basis of that study focusing on the grandiose side of narcissism, it has been endorsed to look at the two subtypes of narcissism, the vulnerable type and the grandiose type, individually, to reveal alterations in binding (Dimaggio & Lysaker, 2015). It has been hypothesised that vulnerable narcissism could be linked to reduced agency as these individuals often experience symptoms of depression or low self-esteem and thus experience diminished agency (Zeigler-Hill et al., 2011). It should be noted, that both subtypes of narcissism can coexist, an individual can have vulnerable and grandiose traits at the same time (Gore & Widiger, 2016; Pincus et al., 2014; Ronningstam, 2009), which could have implications for intentional binding as well.

Lower binding scores, or a reduced sense of agency, is also to be expected for trait anxiety, as the constructs trait anxiety and vulnerable narcissism partly overlap (J. D. Miller et al., 2011) and state fear decreases action binding (Christensen et al., 2019). In line with this, agoraphobia has been proposed to be linked to disruptions in sense of agency revealing the dynamic and relational structure of this condition. It was argued that in the first-person experience, individuals with phobic anxiety tend to mistrust their own reaction to the world. Inhibition, uncertainty and a lack of confidence in their bodies weakens a feeling of control shifting to a locus of control outside their mind and body (Gallagher & Trigg, 2016). A study investigating sense of agency in obsessive compulsive disorder has reported enhanced agency experience via self-report but showed imprecise sensory predictions on an implicit level. Thus, predictions do not serve the function of cancelling and filtering self-produced sensory feedback producing a constant mismatch between expected and actual sensory outcomes of an action; obsessive compulsive patients fail to predict and suppress the sensory consequences of their own actions (Gentsch et al., 2012).

Since trait anxiety and some aspects of psychopathy, such as fearlessness, have been found to be on opposite ends of a spectrum (Neumann et al., 2013), binding effects can be expected to mirror this relationship. While the association between psychopathic traits and criminal offending have been widely investigated, little is known about the underlying processes during an action, the feeling of control and the evaluation of the consequences. It has been reported that psychopathic traits are related to dysfunctions in observing and interpreting actions of others. Thus, highly psychopathic individuals interpreted their own actions correctly, but did not analyse adequately how the consequences of their actions might impact others (Brazil et al., 2011).

Interindividual characteristics associated with variations in anxiety or arousal reactivity are assumed to impact sense of agency. At the same time, emotional states such as state fear (Christensen et al., 2019) and general arousal (Wen et al., 2015) have been reported to influence the sense of agency. But what role does their interaction play? Do personality traits or substance use history interact with emotional states in their effects on sense of agency?

2.6.3 Personality, Substance Use History and Emotional States

By looking at an individual's emotion regulation in response to emotional stimuli, the gap between these research fields can be bridged providing a more holistic view on the sense of agency. Emotion regulation strategies of different personality traits could determine whether an individual's feeling of control is still intact or disrupted by the emotional state. If people with narcissism, psychopathy and low anxiety cope differently with emotions influencing their feeling of control, this has implications for legal culpability according to the German law (§63 Unterbringung in einem psychiatrischen Krankenhaus, §64 Unterbringung in einer Entziehungsanstalt, StGB) and for treatment (Harkins & Beech, 2007), as sense of agency is crucial for the attribution of social and legal responsibility (Haggard, 2017; Haggard & Tsakiris, 2009; Moore, 2016). A body of research has confirmed that personality traits can explain differences in emotion regulation between participants (John & Gross, 2004; Kokkonen & Pulkkinen, 2001). Possibly, personality traits could either work as a buffer or even suppress emotions, whereas other traits could intensify feeling a certain emotion (Ng & Diener, 2009).

A recent study investigated the emotion regulation abilities in grandiose and vulnerable narcissism traits controlling for borderline symptoms (Di Pierro et al., 2017). Results suggested that narcissistic functioning includes emotion dysregulation, but such impairments were related to vulnerable traits rather than grandiose traits. These results are in line with previous studies reporting associations between vulnerable traits and emotional lability, negative affectivity, and internalizing symptoms and, but not between such difficulties and grandiose traits (Dickinson & Pincus, 2003; Given-Wilson et al., 2011; J. D. Miller et al., 2013; J. D. Miller & Maples, 2011; Wright et al., 2013).

Emotional face processing and attention is also altered in higher trait anxiety (Dennis & Chen, 2007). Previous research has indicated that pre-exposure to a short film eliciting anxiety increases sexual arousal when viewing an erotic film compared with pre-exposure to a neutral film (Hoon et al., 1977; Wolchik et al., 1980). Individuals with higher trait anxiety have also been reported to show facilitated engagement and impaired disengagement for emotional stimuli (Koster et al., 2006) suggesting a more intense and persistent emotional response.

Psychopathy, on the opposite pole of the spectrum, is suspected to have different underlying pattern in attention and emotional processing (Anderson et al., 2017; Groat & Shane, 2020). For example, people scoring higher on psychopathy have shown increased task focus and were less impacted by stress-inducing situations than individuals with moderate to low scores (Baskin-Sommers et al., 2012; O'Leary et al., 2010). It has also been reported that psychopathy is associated with a more pronounced and sustained sensory orientation to affective stimuli (Burley et al., 2019; Levenston et al., 2000). An increase in pupil size for the high psychopathy participants for pictures of happy faces was interpreted as a lack of interpersonal trust expressing suspicion to smiling, thus causing arousal (Burley et al., 2019). An increase in heart rate was construed as attention-orienting (Levenston et al., 2000). These results support the view that individuals with high psychopathy show differences in their responses to emotional stimuli, which could potentially explain the differences in binding as well.

Emotion regulation is also supposed to play a crucial role in substance use. Acute drug intoxication serves as a regulation of the current emotional state increasing positive affect, ameliorating a pre-existing negative state, or decreasing craving. More generally, emotion dysregulation is assumed to be both cause for and consequence of drug use (Kober, 2014). Research has found that emotion regulation disturbances in substance disorders may result from impairments in prefrontal functioning, rather than from excessive reactivity to emotional stimuli (Wilcox et al., 2016). Emotional states do not only manifest in our cognition and behaviour dependent on our personality and associated emotion regulation skills, they also go along with changes in our physiological activity.

2.7 Indications in Physiology

Measuring arousal in pupil dilation, skin conductance and heart rate enables us to see a more holistic picture of our emotional response following the call for multi methods approaches in science. Dopaminergic activity whereas, is linked to fewer indications on a physiological level and is currently not accessible at all on a cognitive or behavioural level. One method that has been singled out to index dopaminergic activity though is spontaneous eye blink rates.

2.7.1 Dopaminergic Activity: Spontaneous Eye Blink Rates

Spontaneous eye blink rates are an easily accessible and non-invasive indirect marker of central dopamine function offering a good real time alternative to invasive and expensive techniques such as positron emission tomography. Amongst others, spontaneous blink rates can predict hypo- and hyperdopaminergic activity; with higher blink rates predicting higher dopaminergic function (Jongkees & Colzato, 2016). However, the relationship of dopamine and blink rates is more complex. When given a dopamine agonist, increased eye blink rates in individuals with low baseline blink rates have been noted, whereas decreased eye blink rates have been seen in individuals with high baseline blink rates. This indicates that baseline eye blink rates, and presumably the associated dopamine level, might modulate the effect of dopamine manipulations on blinking (Cavanagh et al., 2014). Similar reductions in blink rates have been observed for sexually arousing pictures (Maffei & Angrilli, 2019), as well as for sexual interest (Hecker et al., 2009). Blink rates have already been used to predict reward information effects modulated by dopaminergic activity on intentional binding (Aarts et al., 2012).

2.7.2 Arousal: Pupillometry, Skin Conductance and Heart Rate

By measuring physiological arousal in pupillometry, skin conductance and heart rate in addition to subjective cognitive arousal via self-report, we can assess arousal via a multi-level approach. Collecting physiological data continuously during the task performance also adds information on another time level since subjectively reported arousal is mostly done in retrospect.

The psychosensory pupil response is a dilation of the pupil through anything the activates the mind, often operationalised as increased arousal or mental effort (Beatty & Lucero-Wagoner, 2000). Particularly sexually arousing and violent materials induce stronger pupil dilation than other kinds of materials (e.g. content such as food, nature, neutral). It can be concluded that pupil diameter is primarily sensitive to events that reliably elicit measurable sympathetic nervous system activity, rather than being a subtle index of how much we like things (Bradley et al., 2017). Also, studies have reported that pupillary changes are larger when viewing emotionally arousing pictures, independent of the valence (Bradley et al., 2008; Partala & Surakka, 2003).

Skin conductance is an independent indicator of sympathetic activity (Boucsein et al., 2012). Largest skin conductance responses have been reported for emotional arousal particularly when viewing pictures depicting threat, violent death, and erotica (Bradley et al., 2001) and sizable literature has shown that skin conductance is sensitive to the presentation of sexual stimuli in several modalities: text, fantasy, slides and films (for a review see Rosen & Beck, 1988).

Although heart rate is determined by both, sympathetic and parasympathetic, it is mainly regulated by the parasympathetic system (Akselrod et al., 1981; Craft & Schwartz, 1995; Mendelowitz, 1999). Many studies have failed to show a linkage between different emotional states such as sexual arousal and heart rate specifically (Heiman, 1977; Laan et al., 1995), but a recently published study claimed a positive correlation between the three arousal measures, pupil dilation, larger response in skin conductance and higher heart rate in an emotional face task (Wang et al., 2018). Combining these three arousal measures on a physiological level with self-reports on a cognitive level, provides the opportunity to see a more holistic view with continuous data on the participants emotional state.

3 Summary of the State of Research

The sense of agency research is of growing research interest with important implications for the understanding of consciousness and motor control, clinical and neuropsychological diseases, and it is the basis of moral and legal responsibility in our society—which is the focus of this work.

Several implicit methods have been used to measure sense of agency, the most widespread of which is intentional binding assessed with the Libet clock or the interval estimation task. Intentional binding presupposes that if an action is intentional and feels controlled by the actor, a binding effect can be observed in form of a subjective compression of the time interval between an action and its outcome. In the Libet Clock task, temporal binding is indicated by a forward shift in the judged time of an action toward its outcome (action binding) and the backward shift of an outcome toward a causal action (outcome binding). These components of intentional binding—action and outcome binding—are driven by distinct underlying mechanisms and should therefore be considered separately.

Up to this point, research has pointed out that our sense of agency adjusts in a flexible way to our environment, for instance in emotional states. Lower action binding has been found for the negative fear and anger and higher binding for unspecific general arousal. However, positive or ambiguous emotional states have been neglected so far, although criminal behaviour can also be driven by sexual desire for example. However, sense of agency does not only vary by contexts, it also seems to vary between people. Some individual characteristics such as grandiose narcissism, schizotypy and schizophrenia have been linked to alterations in binding, but more attention should be drawn to other aspects that are relevant for sentencing and treatment such as psychopathy, low trait anxiety, vulnerable narcissism and substance use history. As personality traits differ in their emotion regulation strategies and coping mechanisms, the extent of the influence of emotional states might vary between people, so that it stands to reason to look at the interaction of personality traits and emotional states as well.

In terms of an underlying rational of why sense of agency varies, the dopamine hypothesis has been outlined by several researchers. First evidence has been found for the role of dopamine in the control of voluntary action: by modulating dopamine functioning with reward and positive affect intentional binding was enhanced. Yet there is a lack of other operationalisations in the sense of agency research to test this theory. We aim to close this gap by conducting three intentional binding studies: first finding determinants interindividually, then inducing emotional states to produce changes intraindividually and finally exploring the interactive effects of interindividual characteristics and intraindividual responses to emotional states while controlling for arousal and indexing dopaminergic activity. Selection of emotional states and interindividual characteristics were driven by their relevance for criminal behaviour and suitability as a proxy for dopaminergic activity.

4 First Study[1]

4.1 Goals and Hypotheses

The goal of the first study was to find determinants for intentional binding in substance use history and personality. Previous experiences have manifested that dopaminergic drugs boost intentional binding under intoxication (Moore et al., 2010; Moore et al., 2011). Substance use history might influence the sensitivity of receptors and/or transporters of the dopaminergic system causing a drug-induced deficit in the dopaminergic function (Narendran et al., 2005) and lower availability of dopamine is associated with a weaker intentional binding (Aarts et al., 2012; Graham et al., 2015). Therefore, we hypothesise reduced intentional binding in substance users compared to non-users.

In terms of personality factors, evidence exists for a stronger intentional binding in narcissists (Hascalovitz & Obhi, 2015). We will extend the current state of research by differentiating between the vulnerable and grandiose type of narcissism (Wink, 1991), expecting higher intentional binding in people with grandiose narcissism and reduced intentional binding in people with vulnerable narcissism (Dimaggio & Lysaker, 2015).

4.2 Materials and Methods

4.2.1 Participants

Power analyses were run with G*Power 3.1. Previous research for narcissism and intentional binding has found overall binding values for high narcissism scores M = -157.40 (SD = 51.08) and low narcissism scores M = -100.20 (SD = 45.94) (Hascalovitz & Obhi, 2015). Power analysis for one tailed for independent t-tests with a = .05, β = .95, and Cohen's d = 1.177 calculated a necessary sample size of N = 34. An experiment using ketamine as a model for psychosis reported

[1] The results presented in this chapter were published in advance in: Render, A. & Jansen, P. (2019). Dopamine and sense of agency: Determinants in personality and substance use. PLoS ONE 14(3)

overall binding values of placebo $M = 45$ ($SD = 69$), ketamine administration M = 72 ($SD = 70$) (Moore et al., 2011). Power analysis for independent *t*-tests with $a = .05$, $\beta = .95$, and Cohen's $d = .388$ calculated a necessary sample size of $N = 145$. Although the power analysis for narcissism showed that only a small sample size is required, more participants were recruited with regards to effects for the different substances.

In total, 210 participants were recruited for the study via flyers and social media platforms. Participants were informed about the purpose of the study and gave their written consent prior to participation. The study was conducted according to the ethical guidelines of the Helsinki Declaration. In accordance with conditions outlined in guidelines from the German Research Society (DFG, Deutsche Forschungsgesellschaft), seeking approval from a research ethics board was not required for this study: Research bearing no additional risk beyond daily activities does not require such approval. We communicated all considerations necessary to assess the ethical legitimacy of the study. We thus ensure that our research approach is in line with national and international human research ethics policies.

Data were analysed de-identified. Participants gave information about their age, ranging from 17 to 34 years, $M = 23.33$ ($SD = 3.52$) and gender; 84 (40.0%) participants identified as male, 126 (60.0%) as female. IQ measured by the Trail Making Test was $M = 118.35$ ($SD = 15.97$) ranging from 88 to 145, to ensure that both groups (substance users and controls) were demographically similar. The majority of the participants were students ($N = 200$) who studied psychology (30), sport sciences (99), arts and humanities (36), criminology (4), law (5), natural science (8), and other disciplines (18). Comparing both groups, participants with substance use history (defined as consume beyond cannabis) were on average three years older than controls (users' age $M = 25.01$, $SD = 3.71$, controls $M = 22.27$, $SD = 2.94$, $t(208) = -5.931$ $p < .001$), and IQ was lower in participants with substance use history (non-users $M = 120.72$, $SD = 15.61$, users $M = 114.51$, $SD = 15.87$, $t(197) = 2.712$ $p = .007$). There were different gender ratios, more participants identified as female in the control group (N = 129, 40 male, 89 female), whereas more participants identified as male in the substance use group (N = 81, 44 male, 37 female).

4.2.2 Apparatus and Stimuli

4.2.2.1 Intentional Binding

As already mentioned, intentional binding or temporal binding can be measured with different tasks, such as the Libet clock or the interval estimation (also interval reproduction) task. As the Libet Clock task has been shown to be more reliable and valid measure for binding (see Introduction) (Tanaka et al., 2019), we used the Libet Clock task in all three studies.

To assess binding, the method of Haggard et al. (2002) was applied as a guiding procedure. The experimental design was generated by the description of Aarts and van den Bos (2011). To program the intentional binding task for the first and second study, a code with HTML5 Application Programming Interfaces (APIs) that maximises accuracy and timing precision was modified. It included the following features: CSS animations for presenting visual stimuli, web audio API for presenting auditory stimuli, and DOM event timestamps for logging user interaction (Garaizar et al., 2016).

In the task, the participants watched an analogue clock, marked with numbers in intervals of 5 (0, 5, 10, 15, 20, 25, 55). The duration of one clock rotation was 2560ms. In each trial, the clock rotated twice; the events, key presses and/or tones, and participants time estimation of the events, occurred in the second lap of each trial. The task consisted of four different blocks, two baselines and two agency blocks. The order of blocks was randomised between participants (Figure 2).

Baseline action: The participants watched the analogue clock and pressed the space key whenever they wanted to in the second lap. Afterwards they reported the position of the clock hand at the time of pressing the key on the clock face.

Baseline outcome: The participants watched the analogue clock and heard a tone at a random time. Afterwards they reported the position of the clock hand at the time of hearing the tone on the clock face.

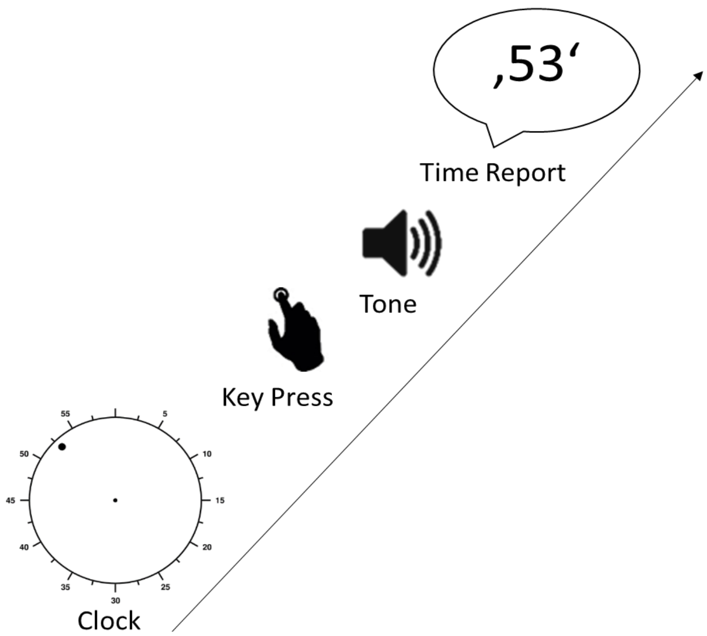
Agency action: The participants watched the analogue clock and pressed the space key whenever they wanted to in the second lap. A tone followed with a delay of 250ms. Afterwards they reported the position of the clock hand at the time of pressing the key on the clock face.

Agency outcome: This block is identical to agency action, but this time the participants reported the position of the clock hand at the time of hearing the tone on the clock face.

In the three blocks in which the participants pressed the key, they were asked to let the clock rotate once before pressing the key to get adjusted to the speed of the clock (Garaizar et al., 2016), and not to press the key at a certain time (e.g., always at the same time or only at the interval marks of 5). In addition, the instruction indicated that they should be as precise as possible (in intervals of 1) in their time estimation about the events. Each block consistent of 20 trials (Moore et al., 2010).

Figure 2

Intentional binding task: illustration of an agency trial.



4.2.2.2 Trail Making Test

The Trail Making Test (ZVT, Oswald & Roth, 1987) measures cognitive processing speed. The test consists of four pages, where the numbers 1 to 90 are arranged in a scrambled order in a matrix of 9 rows and 10 columns. The participants had to connect the numbers as quickly as possible in the correct ascending order, measuring the total time for each page. The test duration was about 5 minutes. The evaluation revealed ZVT scores, which were transferred to corresponding IQ values. The correlation (e.g. Raven-SPM, CFT-30) ranged between r = .60 to .80. The test–retest reliability as well as the internal consistency of the ZVT was about .90 to .95 (Vernon, 1993).

4.2.3 Questionnaires

4.2.3.1 Demographics

Participants reported gender, age, studies, and profession.

4.2.3.2 Narcissism Inventory

Narcissism is measured by the Short Version of the Narcissism Inventory (NI-20) (Daig et al., 2010). This version is composed of four factors: 1) threatened self, with eight subscales (helpless self, loss of control over affects and impulses, de-realization/depersonalization, basic potential of hope, worthless self, negative bodily self, social isolation, and withdrawal into feelings of harmony); 2) classic narcissistic self, including four subscales (self-grandiosity, longing for an idealised self-object, greed for praise and reassurance, and narcissistic furore); 3) idealistic self, with four subscales (self-reliance ideal, object devaluation, idealizing values, and symbiotic self-protection); and 4) hypochondriac self, with the subscales of hypochondriac expression of fear and narcissistic gain from illness. The Cronbach's alpha was above .7. The factor structure was confirmed by an exploratory and confirmatory factor analysis (Daig et al., 2010). Threatened self represents the vulnerable type and classic narcissistic self the grandiose type; only these two scales will be used for analysis.

4.2.3.3 Substance Use History

The items to gather information about the substance use history of the participants were self-generated from the AUDIT questionnaire of the addiction research network Baden-Württemberg UKL Freiburg (Babor et al., 2001), classifying the use of alcohol. There were two categories: ever consumption and prior-year average consumption of alcohol, nicotine, prescription pharmaceuticals (painkiller, tranquilizer, medication for physiological diseases), and illegal drugs (cannabis, amphetamine, ecstasy, LSD, mushrooms, ketamine, cocaine). In addition, the amount, frequency, and years of use were registered for each substance.

4.2.4 Procedure

The study took part at the University of Regensburg, and the duration was roughly 50 minutes. Sessions started with the ZVT (Oswald & Roth, 1987), followed by the computer-based intentional binding task. The second part of the study included questionnaires online presented on the Sosci-Survey platform.

4.2.5 Statistical Analysis

The intentional binding paradigm included measures for binding of action (key press, bias in the perception of action, drift towards the tone) and binding of outcome (tone, bias in the perception of tone, drift towards the action) (Haggard et al., 2002). Actual time was subtracted from perceived time in each trial in order to determine the perception error. Action binding was calculated by subtracting the median error of perceived keypress time in the baseline action block from the median error in the agency action block (agency action – baseline action); outcome binding was calculated by subtracting the median error of perceived tone time in the agency outcome block from the median error in the baseline outcome block (baseline outcome – agency outcome) (Moore et al., 2010; Moore et al., 2011). To compute overall binding, action and outcome binding scores were summarised (action binding + outcome binding). As there was a limited number of trials in each block, medians rather than means were used to eliminate outliers (Pockett & Miller, 2007). A higher binding score refers to a smaller interval in perception between key press and tone, reduced binding is indicated by a smaller binding score (larger interval between key press and tone).

The Pearson correlation coefficient was calculated to examine the link between intentional binding, personality factors and substance use. One-tailed t-tests were conducted for the highest (75^{th}) versus lowest (25^{th}) percentiles in narcissism types and different groups of substance users versus the control group.

The alpha error accumulation for the three questionnaires was calculated by using the formula 1 – $(1-0.03)^3$. Thus, the alpha error was 8.73% instead of 5%. The significance level was corrected according to Bonferroni, and the *p*-value was set to $p = .017$ to reach significance.

4.3 Results

4.3.1 Intentional Binding and Demographics

Due to technical errors, data from eight participants in intentional binding could not be used (participants with substance use history = 3, controls = 5 missing). The mean intentional binding was $M = 84.70$ ($SD = 136.41$, $N = 202$). The mean shift in the baseline action was $M = 49.44$ ($SD = 95.07$), mean shift in the agency action condition was $M = 91.22$ ($SD = 117.76$), mean shift in the baseline outcome condition was $M = 58.93$ ($SD = 55.36$), and mean shift in agency outcome was $M = 16.01$ ($SD = 128.22$). Action binding was $M = 41.76$ (SD 77.88), and outcome binding was $M = 42.93$ ($SD = 118.21$). No difference (in overall binding) could be observed for gender (male $M = 81.67$, $SD = 142.50$, female $M = 86.73$, $SD = 132.74$, $t(200) = -.258$ $p = 797$), age, nor IQ (table 1).

4.3.2 Determinants of Intentional Binding

To understand the nomological network of the intentional binding and the examined variables, table 1 shows all correlation coefficients to intentional binding.

Table 1

Pearson correlation coefficients for determinants and intentional binding (overall).

Variable	*r*	*p*
Age (one-tailed)	-.103	.073
IQ (two-tailed)	-.011	.878
Personality (one-tailed)		

Threatened Self (vulnerable narcissism)	-.146	.020
Hypochondriac Self	-.007	.461
Classic Narcissistic Self (grandiose narcissism)	-.076	.142
Idealistic Self	.029	.342
Narcissism (overall)	-.078	.135

Note: Significance: $p \leq .017$

4.3.2.1 Intentional Binding and Personality

Contrary to results previously reported in the literature, no correlation to general narcissism (r = -.078 p = .269) was found. But when splitting the sample into the 25th and 75th percentiles of the subscales threatened self (vulnerable type) and classic narcissistic self (grandiose type), the vulnerable type showed a weaker shift in perception of the key press if the tone followed (agency action trials), and consequently a weaker intentional binding (total binding), than people with low scores of vulnerability (table 2). Independent t-tests showed differences ($t(2470)$= -7.529 p < .001) in the means of threatened self in this study (N = 209, M = 1.920, SD = .635) compared to the means in the norms (N = 2262, M = 2.620, SD = 1.330), and threatened self was significantly smaller in the current study in comparison to mean norms (patients from Charité Clinic, Berlin).

Table 2

Intentional binding and threatened self.

Subscale	M_{high}	*SD*	M_{low}	*SD*	*t*-test	*p*
Baseline action	42.95	88.36	52.70	95.41	.541	.295
Agency action	69.26	88.93	127.77	132.15	2.629	.005
Baseline outcome	53.23	54.21	64.61	49.54	1.125	.132
Agency outcome	26.31	112.24	21.33	144.45	-.196	.423

Total binding	53.22	122.32	118.36	172.88	2.208	.015

Note: One-tailed *t*-tests for intentional binding conditions, 75th (high, *N* = 50) versus 25th (low, *N* = 55) percentiles in the narcissism subscale threatened self. Significance $p \leq .017$.

The grandiose type discriminated neither in binding nor in the different blocks, as presented in table 3. Means of grandiose narcissism in this study did not differ from and the mean norms (this study $N = 209$, $M = 2.375$, $SD = .645$, norms $N = 2262$, $M = 2.520$, $SD = 1.190$, $t(2470) = -1.737$ $p = .083$) (patients from Charité Clinic, Berlin).

Table 3

Intentional binding and classic narcissistic self.

Subscale	M_{high}	*SD*	M_{low}	*SD*	*t*-test	*p*
Baseline action	59.35	102.20	60.43	95.88	.055	.479
Agency action	82.10	108.20	103.74	120.25	.933	.177
Baseline outcome	65.50	65.68	58.99	57.84	-.526	.300
Agency outcome	19.62	118.50	10.84	135.38	-.340	.368
Overall binding	68.63	106.22	91.46	147.00	.867	.194

Note: One-tailed t-tests for intentional binding conditions, 75th (high, *N* = 44) versus 25th (low, *N* = 56) percentiles in the narcissism subscale scores for classic narcissistic self. Significance $p \leq .017$.

4.3.2.2 Intentional Binding and Substances

Table 4 lists how many participants have consumed each substance (ever consumed).

Table 4

Consumed substances (ever).

	Cannabis	Ecstasy	Amphetamine	Mushrooms	LSD	Cocaine	Ketamine	> Cannabis
Yes	131	63	57	44	43	49	34	81
No	78	146	152	165	166	160	175	129

Note: Absolute number of users.

Table 5 focuses on frequency of use of different substances. Only the correlation for ketamine reached significance.

Table 5

Pearson correlation coefficients (one-tailed) for frequency of use and intentional binding.

Frequency of Use	*r*	*p*
All participants		
Alcohol	-.095	.140
Nicotine	.108	.079
Cannabis	-.056	.222
Participants with Substance Use History		
Tranquilizers	.143	.106
Psychotropics	.029	.400
Cannabis	.185	.062
Amphetamine	.168	.071
Ecstasy	.196	.043
LSD	.220	.027
Mushrooms	.230	.022

Ketamine	.250	.014
Cocaine	.136	.118

Note: Significance $p \leq .017$, substance use history = consumption beyond cannabis $N = 78$

Regarding substance use (ever), there were several differences in binding (table 6). Independent t-tests showed significant differences in intentional binding for drug users who had consumed cannabis, ecstasy, or cocaine. Additionally, a new variable was computed by summarizing all users who had consumed other drugs besides cannabis (at least one additional substance) compared to the control group: Consumers (cannabis, ecstasy, or cocaine and new score substances beyond cannabis) showed significantly reduced intentional binding compared to controls.

Table 6

Differences in intentional binding (overall binding) between drug users and controls.

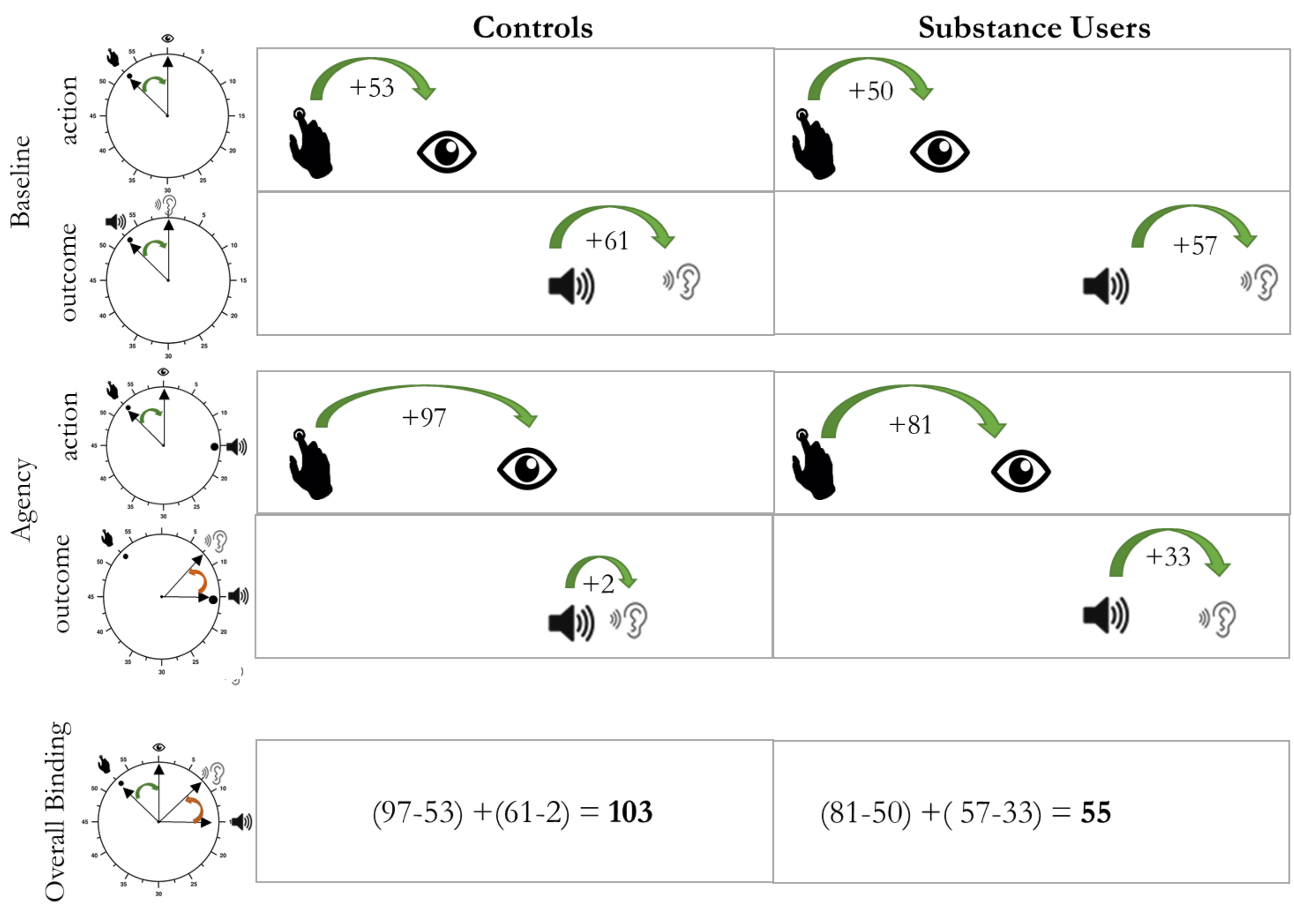
Substance	M_{users}	*SD*	$M_{control}$	*SD*	*t*-test	*p*
Cannabis	67.51	136.31	111.29	133.13	2.227	.014
Ecstasy	51.87	139.51	97.77	133.28	2.203	.015
Amphetamine	60.80	141.07	92.84	134.12	1.489	.069
Mushrooms	67.49	132.90	88.58	137.47	.898	.185
LSD	66.29	147.33	88.63	133.63	.935	.176
Cocaine	43.74	124.84	96.38	137.85	2.340	.010
Ketamine	76.42	138.23	85.63	136.45	.359	.360
> Cannabis	55.37	134.50	103.15	134.26	2.454	.008

Note: One-tailed t-tests for intentional binding in users versus controls for each substance. Significance $p \leq .017$. Drug users = consumption beyond cannabis.

Figure 3 illustrates the alterations in perception. One can conclude that participants with history of substance use have greater intervals of binding between action (key press) and event (tone), due to later perception of the time of key press and the tone (reduced overall binding).

Figure 3

Intentional binding of controls versus substance users. Illustrated are shifts in perception (difference = perceived time minus actual time) for baseline action, baseline outcome, agency action, agency outcome and overall binding. Substance users = consumption beyond cannabis. Interval between key press and tone is larger for substance users, i.e. overall binding is reduced.



4.4 Discussion

We hypothesised a negative link between substance use history and intentional binding as substance use is assumed to go along with alteration in the dopaminergic system namely lower dopamine levels in the long term, attributing for a reduced intentional binding. In terms of personality factors, we extended the current state of research by differentiating between the vulnerable and grandiose type of narcissism (Wink, 1991), expecting higher intentional binding in individuals with grandiose narcissism and reduced intentional binding in people with vulnerable narcissism (Dimaggio & Lysaker, 2015).

We found significant determinants for intentional binding. In terms of substances (consume ever): cannabis, ecstasy, cocaine and all substances beyond cannabis taken together corelated with reduced binding. For frequency of use, only ketamine showed a significant correlation with overall binding. With regards to personality, higher vulnerable narcissism was associated with reduced intentional binding, no effects were found for grandiose narcissism.

4.4.1 Placement of Results in Current State of Research

4.4.1.1 Intentional Binding and Narcissism

Previously, a stronger intentional binding, measured with the Libet Clock task, has been found in narcissists (Hascalovitz & Obhi, 2015). In this study, we distinguished between two forms of narcissism, since there has been evidence that narcissism occurs in two subtypes: the vulnerable and the grandiose type (Zeigler-Hill et al., 2008). Dimaggio and Lysaker (2015) supposed that the two types of narcissists also differ in their intentional binding. According to this, the vulnerable subtype experiences reduced agency, particularly in self-esteem threatening situations, as it already unstable, e.g. when being rejected in a romantic relationship (Zeigler-Hill et al., 2011). In contrast, the grandiose subtype is assumed to experience hyper-agency (Dimaggio & Lysaker, 2015). Our results represented the vulnerable subtype in the factor of the threatened self, which contained, among others, the aspects of helpless self, worthless self, negative bodily self, and social isolation.

These facets embody the vulnerability–sensitivity type (Daig et al., 2010), the covert form of narcissism. Our results confirmed a reduced sense of agency in the 75th percentile compared to the 25th percentile of vulnerable narcissism. Although the vulnerable narcissism mean values in this study were lower than the norm values, weaker intentional binding could still be observed, even on a non-clinical level.

Grandiosity-exhibitionism was represented by the classic narcissistic self (Daig et al., 2010) in our study. The mean values for grandiose narcissism did not differ from the norm mean values in a clinical sample. However, no results were found for this subtype in this study. Previous findings have shown negative correlations between social desirability and self-reported narcissism questionnaires. The attempt to hide narcissistic tendencies or personality traits for reasons of social desirability may explain the lack of results for grandiose narcissism (P. J. Watson & Morris, 1991). Another explanation for the inconsistency in results across the studies could be the use of different questionnaires to assess narcissism. Hascalovitz and Obhi (2015) used the English version of the narcissistic personality inventory (NPI) (Raskin & Hall, 1979), a questionnaire for grandiose narcissism and found stronger binding. Our results are based on the German version of the Narcissism Inventory (NI-20) (Daig et al., 2010) and we did not find any effects for the grandiose narcissism subscales. To the best of our knowledge, there are no studies investigating the correlation between these two narcissism questionnaires. However, it has been postulated that the NI covers narcissism as a broader construct including moral values, sexual behaviour, cognitive style and learning deficits, whereas the NPI neglects these aspects (Triller, 2003).

4.4.1.2 Intentional Binding and Substances

(Lifetime) Experiences with the substances cannabis, ecstasy, or cocaine but also with substances in general that go beyond cannabis, were significantly related to reduced intentional binding in our study. In the baseline conditions, the values of perception were similar, negating a prolonged time perception in general for substance users. However, alterations emerged in agency trials (key presses and tones), showing a delay in perception of the tone in substance users.

Most of the examined participants reported poly-substance use and variations in amount, frequency, and years of use, which limits the interpretation for single substances. Ideally, participants who have consumed only a single substance for a longer period and high frequency should be examined to see the effect of each substance individually, but these inclusion criteria would reduce the sample size immensely. Our study included some participants who reported only a single drug consumption, but the number of these participants was too small to generalise the results to specific substance. Considering that the sample was heterogeneous and not on a clinical level, substance use still seems to produce a robust effect in the binding mechanism. Potentially, results of a patient sample suffering from addictions were more distinct since the participants in our study have not been diagnosed with an addiction or as having difficulties in their usage habits. The connecting feature of the participants is likely to be lower dopamine levels; thus, our results indicate an involvement of dopamine for intentional binding, even on a level that does not rise to a clinical one.

4.4.2 Limitations and Outlook for Following Studies

It would be elucidating to look at components of intentional binding individually to understand whether and how personality factors and substance use history are related to changes in the feeling of control over actions and outcomes in the following studies. It has been outlined, that action and outcome binding are driven by distinct mechanisms (Tanaka et al., 2019), therefore, it could be expected that they show different pattern in personality traits or in response to emotional states as well. If there are differences between the components, this would change the implications for treatments. Other personality traits that should be taken into account are psychopathy and low trait anxiety as they are known to be risk factors for offending behaviour (Köhler et al., 2009; Kosson et al., 1990; Leue et al., 2004) stressing the importance of these personality traits for agency research.

Secondly, as counterparts of long-term changes associated with personality, short-term adjustments in our sense of agency should be investigated challenging its flexibility. Up to this point results for fear, anger (Christensen et al., 2019) and arousal (Wen et al., 2015) have been reported but other positive or ambiguous arousing states associated with dopamine release such as sexual arousal (Oei et al., 2012) have been neglected so far.

4.4.3 Conclusion

This study determined factors that are associated with alterations in intentional binding. Individuals who reported more substance use history and individuals scoring higher on vulnerable narcissism both showed reduced binding compared to controls. These results support the dopamine hypothesis, suggesting decreased binding in states associated with lower accessibility of dopamine. The following study can build on these findings for low dopaminergic states and clarify whether high dopaminergic states such as sexual arousal cause alterations in binding as well. More attention should also be drawn to the effects of personality and substance use history on the binding components separately as this remains in the dark up to this point.

The results of the first study for narcissism and substance use history as equivalents of low dopaminergic activity inspired us to test states associated with high dopaminergic activity: As sexual arousal associated with dopamine release (Damsma et al., 1992; Giuliano & Allard, 2001; Karama et al., 2002; Oei et al., 2012; Ponseti et al., 2006; Rupp & Wallen, 2008; Stoléru et al., 1999), plays a crucial role for the evaluation of the responsibility of our actions in a legal context, we wanted to investigate, whether sense of agency is impacted by it temporarily.

5 Second Study[2]

5.1 Goals and Hypotheses

Previous research has provided evidence for an increased intentional binding in high arousal and neutral valence (unspecific general arousal) (Wen et al., 2015) and reduced action binding in high arousal and negative valence (fear and anger) (Christensen et al., 2019)—but what about high arousal and ambiguous or positive valence (e.g. sexual arousal)? Consistently co-occurring with ambivalent affect (e.g. Peterson & Janssen, 2007), sexual arousal is assumed to act as an inhibitor of cognitive processes such as perception (Most et al., 2007) or memory (Mather & Sutherland, 2011). It has also been shown that experiencing lower inhibitions in sexual arousal affects predictions of the individual's own judgments, decision-making processes and behaviour, self-control and sexual self-restraint (Ariely & Loewenstein, 2006; Ditto et al., 2006; Skakoon-Sparling et al., 2016; Skakoon-Sparling & Cramer, 2016), processes that are likely to share mechanisms with intentional binding. Sexual arousal captures attention impairing other processes in a similar manner as arousing states with negative valence (Most et al., 2007). We therefore expected sexual arousal to impair binding.

Furthermore, as in previous studies (Christensen et al., 2016; Christensen et al., 2019), we expected to see alterations in action binding rather than in outcome binding. This stands to reason as action binding is known to be specific to conditions, where an action is internally generated and executed voluntarily (Borhani et al., 2017) providing a direct measure to show how close the mental representation of an action is linked to its outcome (Christensen et al., 2019). On the basis of the meta-analysis of Tanaka et al. (2019), it can be concluded that action and outcome binding are respectively driven by both predictive and inferential processes, but they show different pattern in

[2] The results presented in this chapter were published in advance in: Render, A. & Jansen, P. (2020). Influence of Arousal on Intentional Binding—Intact action binding, impaired outcome binding. *Attention, Perception & Psychophysics*, 1-11.

their underlying mechanism, which is why both components should be examined separately. Action binding captures a specific impairment in action planning or generating an action outcome prediction (Tanaka et al., 2019). A highly emotional state might impair the preciseness of these prediction processes. From this, we expect sexual arousal to decrease action binding whilst not affecting outcome binding.

5.2 Materials and Methods

5.2.1 Participants

Following Christensen et al. (2019) we ran a power analysis with G*Power 3.1 using the a priori procedure for ANOVA mixed measures (repeated measures, between within interactions, 3 groups, 2 measures, η_p = .168, a = .05; power = .95, correlation among repeated measures r = .7 (Cohen, 1988)): a sample size of 84 was determined. The design included three groups, a sexual arousal group and two control groups. The second control group was recruited to examine possible confounding effects of the intertrial-images in the second intentional binding task in two of the three groups (see Design and Procedure).

In total, 90 individuals participated in this study pseudo-randomly assigned, considering gender balance, to one of three groups. Analyses were conducted on de-identified data. 89 participants gave information about their age, ranging from 18 to 29 years, M = 21.72, SD = 2.11, one participant chose not to answer. 39 (43.3%) participants identified as male, 51 (56.7%) as female, 89 participants classified themselves as heterosexually oriented, and one female participant reported to be bi-sexually oriented.

Within the different groups, gender balance was given for the sexual arousal group (N = 34, N_f = 14, N_m = 17) and neutral group with intertrial-images (N = 31, N_f = 17, N_m = 14). The second control group without intertrial-images was smaller and included more female than male participants (N = 25, N_f = 18, N_m = 7). There were no differences in age between the groups (sexual arousal M = 21.82 SD = 2.11, neutral with screenshots M = 22.00 SD = 2.44, neutral without screenshots M = 21.24 SD = 1.61, $F(2, 86) = .955$ $p = .389$).

Ethical approval for the study was obtained from the Research Ethics Committee of the University of Regensburg (project code 18-1203-101), prior to commencement of any testing activities. Participants were informed about the purpose of the study and gave their written consent prior to participation.

5.2.2 Apparatus and Stimuli

5.2.2.1 Intentional Binding

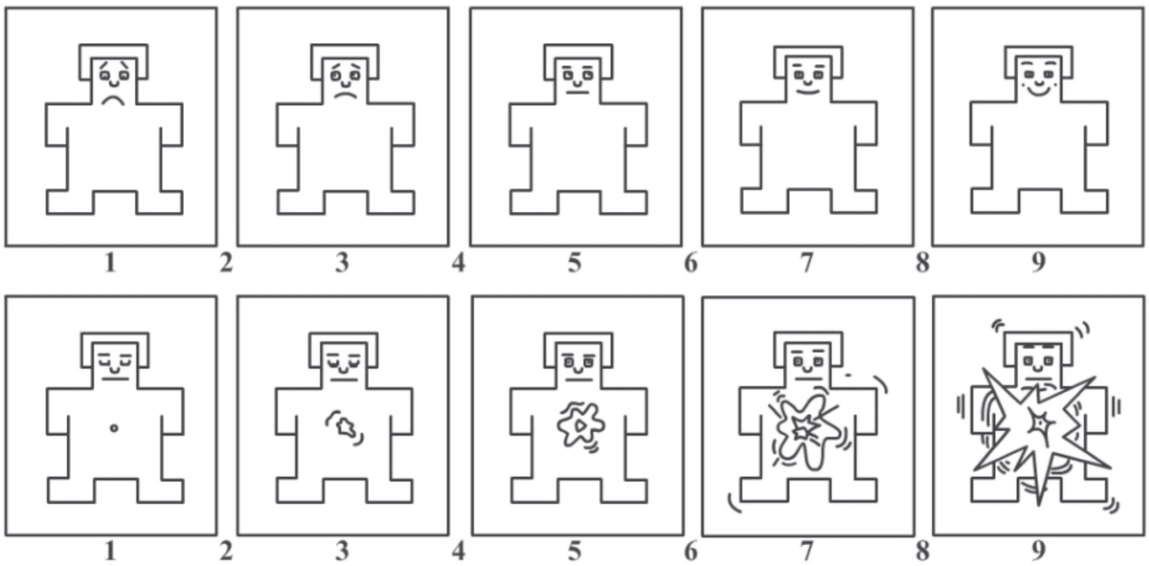
Analogue to the first study, intentional binding was measured with the Libet Clock task (Haggard et al., 2002). Therefore, the same code provided by Garaizar et al. (2016) was modified. Each of the four intentional binding blocks contained 20 trials, order of blocks was randomised between participants. Still inter-trial images were used for the post-intentional binding task in the sexual arousal group and one of the control groups.

5.2.2.2 Questionnaires

Affective Ratings. A paper and pencil version of the SAM (Lang, 1980) was used to record self-experienced emotional and arousal states (figure 4). Ratings were made on a 9-point Likert scale for valence and general arousal (Carvalho et al., 2012). Following Philippot (1993) participants were instructed to report what they had actually felt in response to viewing the film clip, rather than what they believed they should feel, and, what they felt at the time they viewed the film clip, not their overall mood. Since the SAM measures general arousal and not sexual arousal specifically, we added one item measuring the impact of sexual arousal in the sexual arousal group (1 = not at all sexually arousing, 9 = very much sexually arousing).

Figure 4

Adapted version of the SAM (Lang, 1980) for valence (top) and (general) arousal (bottom) ratings.



5.2.3 Procedure and Experimental Design

Sessions started with the SAM to assess self-reported valence and arousal, followed by the first computer-based intentional binding task. After completing the first part, participants watched a 6.5 minutes film clip either showing a sexually arousing scene (Threesome scene from the movie "Love", 2015, Gaspar Noé) or a documentary film clip about the solar system/planets depending on the group they were assigned to. Thus, both control groups watched the same documentary film clip. After watching the film clip, participants completed the SAM for arousal and valence afterwards for the second time. Then, post-induction, the second intentional binding task was conducted. To ensure that sexual arousal was maintained during the second intentional binding task, still intertrial-images (screenshots) of the pornographic film clip were shown between the trials in the sexual arousal group and still intertrial-images of the documentary clip were inserted in one of the two control groups to guarantee comparability between the two groups. The second control group did not have still intertrial-images so that confounding effects of the images in general on binding could be controlled for. The total duration of the study was roughly 1.5 hours.

5.2.4 Statistical Analysis

5.2.4.1 Manipulation Check

Influence of inter-trial images. Two two-way mixed-ANOVAs (between factor "group", within factor "time") were used to investigate potential effects of the intertrial-images of the two film clips.

Manipulation check of emotional induction. A three-way mixed ANOVA dependent variable SAM scores, between factor "group" (control without intertrial-images, control with intertrial-images and sexual arousal group), and the within factors "emotion rating" (general arousal, valence) and "time" (pre- and post-induction) was performed to confirm arousal manipulation. T-tests for paired samples adjusted with Bonferroni correction (p < .017) were used as post-hoc analyses for arousal ratings to examine the change over time in each group.

Calculation of intentional binding was calculated in the same way as in the first study. Again, smaller values represent greater action binding as it means the key was perceived to be closer to the tone.

5.2.4.2 Main Analysis

Influence of arousal induction on binding. Analyses for influence of emotion induction on binding were conducted separately for each component due to the different pattern of action and outcome binding. Thus, two two-way mixed ANOVAs with the between factor "group" (sexual arousal, control with intertrial-images, control without intertrial-images) and within factor "time" (pre- and post-induction) were conducted for action binding and for outcome binding individually.

Influence of arousal change on binding. In addition, (general) arousal ratings were included in the analyses to control for differences in arousal ratings between the groups. Therefore, the differences between post- and pre-arousal ratings were calculated for each participant and integrated as a covariate in two two-way ANCOVAs (between factor "group" and within factor "time"), one for action binding and one for outcome binding respectively. A Pearson correlation coefficient for (general) arousal change (difference = post-arousal - pre-arousal) and action binding change (difference = post- action binding - pre-action binding) was used to interpret the interaction between action binding and arousal change.

5.3 Results

5.3.1 Manipulation Check

5.3.1.1 Control Groups: Influence of Intertrial-Images

Intertrial-images of the neutral film clip did not influence the post-binding scores. Two two-way mixed ANOVAs (between factor "group", neutral group with vs. neutral group without intertrial-images; within factor "time") were conducted, confirming control groups did not differ from one another, neither in action, nor outcome binding between the two intentional binding measurements (table 7).

Table 7

Two two-way mixed ANOVAs with between factor "group" and within factor "time".

	$F(1, 54)$	p	η^2
Action Binding			
Group	.195	.660	.004
Time	.001	.973	.000
Time * Group	1.525	.222	.027
Outcome Binding			
Group	.045	.883	.001
Time	.315	.577	.006

Time * Group	1.031	.315	.019

Note: Factor "group" = neutral with intertrial-images vs. neutral without intertrial-images

5.3.1.2 Arousal Induction: Subjective Ratings (SAM)

The means and standard deviations for SAM pre- and post-ratings of arousal and valence for each group can be seen in table 8. To assess sexual arousal induced by the erotic film clip specifically, participants in the sexual arousal group were also asked to what extent they evaluated the film clip as sexually arousing (M = 5.24 SD = 1.86); four participants chose not to answer this question.

Table 8

Means and standard deviations for pre- and post-(general) arousal and valence ratings by group (N = 90).

Group		*pre*	*post*
Control without	Arousal	2.96 (1.86)	3.24 (1.90)
Intertrial-images	Valence	6.44 (1.04)	6.00 (1.58)
Control with	Arousal	3.10 (1.90)	3.03 (1.97)
Intertrial-images	Valence	5.84 (1.27)	5.94 (1.26)
Sexual Arousal	Arousal	2.26 (1.19)	4.88 (1.92)
	Valence	5.94 (1.18)	5.71 (1.27)

The three-way mixed ANOVA (between factor "group", within factors "time" and "emotion rating" (arousal and valence) showed significant main effects for time and emotion rating. Significant interactions were observed for time * group, time * emotion rating, and time * emotion rating * group (table 9).

Table 9

Three-way mixed ANOVA between factor "group", within factors "time" and "emotion rating" (N = 90).

	$F(2, 87)$	p	η^2_p
Group	.517	.598	.012
Time	5.632	.020	.061
Time * Group	7.099	.001	.140
Emotion Rating	220.866	.000	.717
Emotion Rating * Group	1.966	.146	.043
Time * Emotion Rating	26.810	.000	.236
Time * Emotion Rating * Group	18.273	.000	.296

*Note: F*actor "group" = sexual arousal vs. neutral with inter-trial images vs. neutral without inter-trial images.

The three-way interaction shows a significant difference between pre- and post-rating in the sexual arousal group ($t(33) = -9.042$ $p < .001$, pre $M = 2.26$ $SD = 2.29$, post $M = 4.88$ $SD = 1.92$), but no significant differences in the two control groups (control with intertrial-images $t(30) = .168$ $p = .868$, pre $M = 3.10$ $SD = 1.90$, post $M = 3.03$ $SD = 1.97$, control without intertrial-images $t(24) = -.573$ $p = .572$, pre $M = 2.96$ $SD = 1.86$, post $M = 3.24$ $SD = 1.90$). As sexual arousal is expected to be an ambivalent emotional state in a laboratory setting, an analogue increase of valence ratings was not predicted and could also not be demonstrated in our data.

5.3.2 Main Analysis

5.3.2.1 Action Binding: Influence of Group

Results of the two-way mixed ANOVA (between factor "group"; within factor "time") did not confirm the hypothesis, no significant effects were found (table 10). Action binding was not affected by sexual arousal specifically.

Table 10.

Two-way mixed ANOVA between factor "group" and within factor "time" for action binding.

	$F(2, 87)$	p	η^2_p
Group	.119	.888	.003
Time	.520	473	006
Time * Group	1.635	.201	.036

Note: Factor "group" = sexual arousal vs. neutral with inter-trial images vs. neutral without inter-trial images.

5.3.2.2 Action Binding: Influence of Arousal Change

The differences between pre- to post-induction for the sexual arousal group confirmed a successful manipulation of sexual arousal. Nonetheless, this did not guarantee comparability of the three groups in arousal level in pre-induction measurements. Hence, the change from pre- to post-arousal ratings was added to the analyses controlling for potential baseline differences independent of design: Post-arousal rating was subtracted from pre-arousal rating for each participant and included as a covariate. A two-way mixed ANCOVA between factor "group", within factor "time" and covariate "arousal change" revealed an interaction between time * arousal change on action binding (table 11).

Table 11

Two-way mixed ANCOVA between factor "group" and within factor "time" and covariate (general) "arousal change" for action binding.

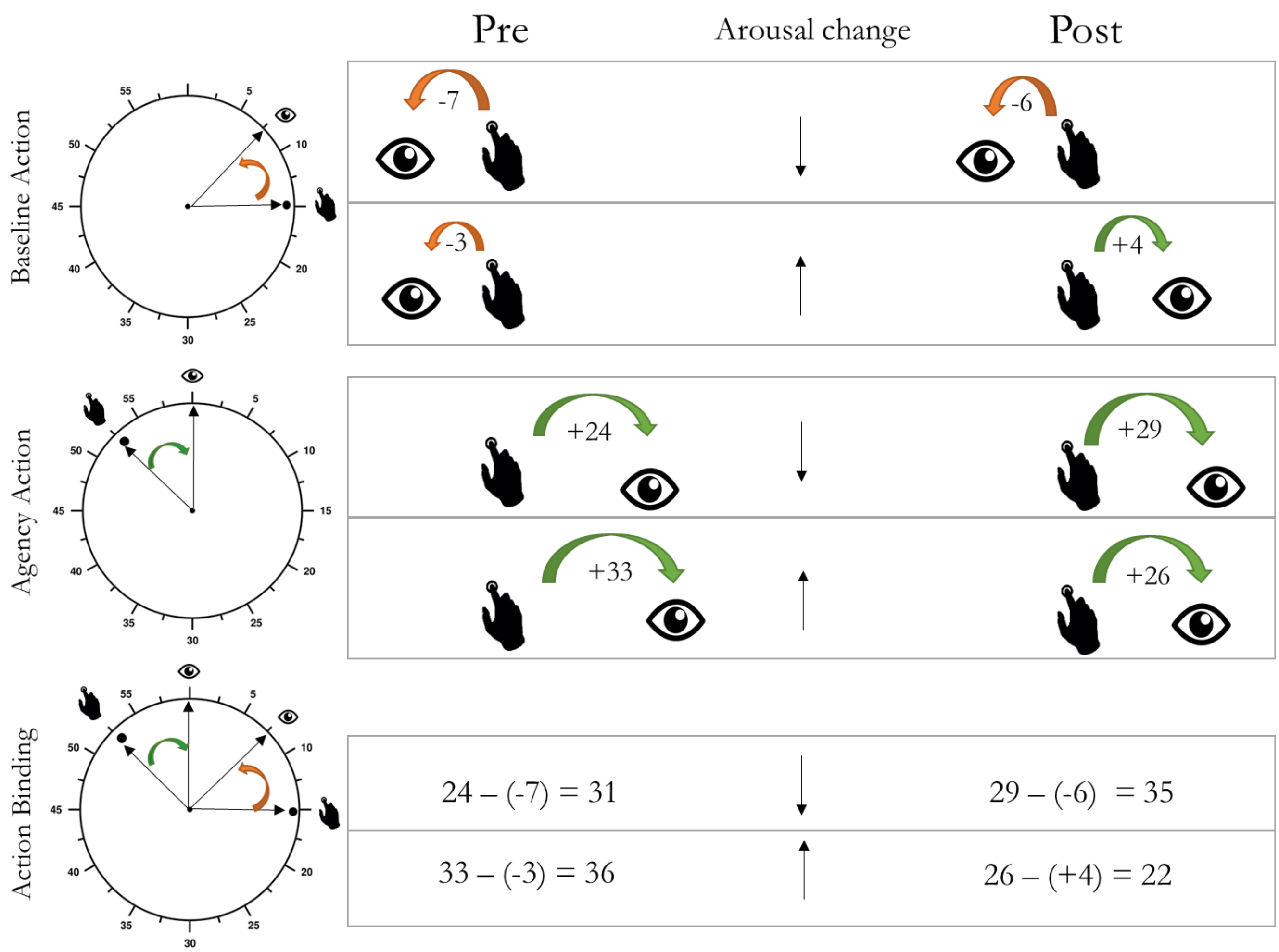
	$F(2, 86)$	p	η^2_p
Group	.120	.887	.033
Time	.132	.717	.002
Time * Group	.766	.468	.017
Time * Arousal Change	6.200	.015	.067

Note: Factor "group" = sexual arousal vs. neutral with inter-trial images vs. neutral without inter-trial images.

A Pearson correlation coefficient was used to clarify the direction of the effect between arousal change as a continuous measure and action binding with differences scores (pre-action binding was subtracted from post-action binding; pre-arousal rating was subtracted from post-arousal rating). These differences correlated negatively with one another (r = -.292 p = .005). Negative values in the arousal differences indicated a decrease in arousal from pre- to post-induction, whereas positive values indicated an increase in arousal over time. Greater values represented greater action binding (key press was shifted towards tone). Hence, greater values in the action binding difference indicated a stronger binding in the post-induction compared to pre-induction, whereas smaller values indicate a weaker binding post-induction compared to pre-induction (key press was not shifted to tone). A negative correlation therefore implies that action binding is reduced in higher arousal and action binding is increased in lower arousal (figure 5).

Figure 5

Baseline action, agency action and action binding scores visualised by median split of (general) arousal change, ↓ = decrease in arousal from pre- to post-task, ↑ = increase in arousal from pre- to post-task, numbers = mean perception error in milliseconds (perceived time – actual time), finger = actual key press, eye = perception of key press.



5.3.2.3 Outcome Binding: Influence of Group

The two-way mixed ANOVA (between factor "group"; within factor "time") for outcome binding did not show significant effects (table 12). Outcome binding was still intact in sexually aroused state.

Table 12

Two-way mixed ANOVA between factor "group" and within factor "time" for outcome binding.

	$F(2, 87)$	p	η^2_p
Group	1.615	.205	.036
Time	.174	.677	.002
Time * Group	.508	.604	.012

Note: Factor "group" = sexual arousal vs. neutral with inter-trial images vs. neutral without inter-trial images.

5.3.2.4 Outcome Binding: Influence of Arousal Change

Analogue to the analysis for action binding, arousal ratings were added as a covariate for outcome binding in order to control for potential differences in the first measurement of the intentional binding task between the three groups. A two-way mixed ANCOVA between factor "group", within factor "time" and covariate "arousal change" over time for outcome binding did not reveal significant effects (table 13). Outcome binding seems to be independent of subjectively reported arousal level.

Table 13

Two-Way mixed ANCOVA between factor "group" and within factor "time" and covariate (general) "arousal change" for outcome binding.

	$F(2, 86)$	p	η^2_p
Group	.123	.885	.003
Time	.050	.824	.001
Time * Group	.548	.540	.013
Time * Arousal Change	.136	.713	.002

5.4 Discussion

The goal of this second study was to investigate the effect of sexual arousal, as a proxy for a state of high dopaminergic activity, on action binding. It was postulated that sexual arousal would impair action binding, whereas no effects were expected for outcome binding.

In line with the hypothesis, outcome binding was still intact in sexual arousal (interaction of group and time n.s.) and not affected by general arousal (interaction of time and general arousal change n.s.) either. Although no significant effects were found for sexual arousal specifically on action binding, the results of the current experiment do support the notion that generally arousing states are associated with a reduction in action binding as measured by the Libet clock task. This is in line with research which has investigated negative arousal states such as fear and anger (Christensen et al., 2019). However, these findings are contrary to previous results of increased intentional binding in general arousal measured with the interval estimation task (Wen et al., 2015). The cause for the inconsistency in results is unclear, however, it may be due to differences in the intensity of arousal experienced by participants, extent of arousal, or the use of different intentional binding measurements in the studies.

5.4.1 Placement of Results in Current State of Research

5.4.1.1 Arousal and Intentional Binding

As stated above, the first possible explanation for the inconsistency between the results of our second study and the findings of Wen et al. (2015) could be that the participant's experience of arousal intensity differed between the two studies. Previous research has shown that arousal can induce opposite effects on task performance in cognitive tasks depending on its intensity: while moderate arousal has benefits for other cognitive processes, high arousal has been associated with impairments (e.g. Peifer et al., 2014). However, the intensity levels of experienced arousal between the two studies cannot be compared, as different self-report measures were used.

Second, the arousal extent induced in the two studies could have been different. (Wen et al., 2015) provided arousal measurements of a second sample of participants that did not perform the intentional binding task. Thus, the arousal levels cannot be linked directly to the intentional binding scores as these values are from 10 different participants that were recruited additionally. These participants evaluated their arousal levels induced by the red colour of the jumping squares with self-report and the physiological arousal was measured via skin conductance. Their design assumes that the response in subjective affect and skin conductance of a small sample can be generalised to a larger, different sample. Although our design included subjective cognitive ratings only, arousal ratings of the participants were linked directly to their binding scores before and after the arousal induction. The differences in subjective affective ratings across the participants within the same emotion induction emphasise the importance of controlling for individual responses to the manipulation.

A third reason for the inconsistency in results could be found in the different approaches of measuring intentional binding. Wen et al. (2015) used the interval estimation task, whereas this study was conducted with the Libet clock task (see general discussion).

5.4.1.2 Action Binding and Dopamine

Our results are in line with the view that action binding is more independent of temporal prediction than outcome binding, and that inaccurate predictions provide evidence of a specific impairment in action planning or generating action outcome predictions, rather than in the matching process of predicted and observed outcomes. As arousing states are associated with alterations in the dopaminergic pathways within different brain areas (Damsma et al., 1992; Giuliano & Allard, 2001), reduced action binding during arousal reflects the changes in the dopaminergic system involved in action execution (Tanaka et al., 2019). Outcome binding is less affected as it is driven by a different pre-activation mechanism (Waszak et al., 2012; Wolpe et al., 2013).

5.4.2 Limitations and Outlook for Following Study

This second experiment rejected effects of sexual arousal specifically on binding, which was contrary to the hypothesis, but it did support the notion that unspecific general arousal reduces binding. However, at this point, it cannot be evaluated whether arousal levels were maintained during the task, as the two affective ratings were only assed before each intentional binding task. Four affective ratings, one before and one after each intentional binding task, could clarify whether arousal levels were sustained during the task performance. On a physiological level, pupil dilation, skin conductance and heart rate could check whether the arousal manipulation during the film clip was successful and whether it is still present during the task performance. Since valence-dependent effects have not been fully understood yet, it might be useful to include an additional emotional state with low arousal such as calm pleasure or sadness to distinguish the effects of arousal and valence.

Lastly, the next experiment could combine the previously found determinants in personality and emotional states. Interactional effects could reveal whether the extent of the disruption in the feeling of control varies through emotional responses and coping mechanisms. For instance, individual differences such as personality, dispositional affect, and genotype have been shown to substantially modulate the bases of emotion processing (Hamann & Canli, 2004). If individuals with higher psychopathy and lower trait anxiety scores, who are more likely to commit offenses (Hare et al., 2000; Knight & Guay, 2006; Porter et al., 2001), show different patterns in the feeling of control when aroused, this would have implications for sentencing and treatment decisions.

5.4.3 Conclusion

The results of our second study are in line with previous research that reported reduced action binding in negative arousal such as fear and anger measured with the Libet clock task (Christensen et al., 2019), but are in contrast with previous findings for unspecific general arousal in intentional binding measured with the interval estimation task (Wen et al., 2015). As effects for arousal were observed for action binding only, which is thought to be more closely connected to the dopaminergic system than outcome binding, these results can be seen a preliminary evidence for the dopamine hypothesis.

Our first two studies revealed reduced intentional binding in certain personality traits and emotional states. In the third study, we were interested in combining the designs of the two previous studies investigating the interactive effects of personality and emotional states on action and outcome binding individually.

6 Third Study[3]

6.1 Goal and Hypotheses

Besides the interactive effects of emotional states and personality traits on binding, a second goal of this third experiment was to gain more insight into the different effects of arousal and valence. Therefore, the emotional state calm pleasure with low arousal and positive valence was added to the design. In line with the second experiment, we expected (sexual) arousal to reduce action binding as other cognitive and perceptual processes have been shown to be impaired (Most et al., 2007; Skakoon-Sparling & Cramer, 2016). Pleasure was assumed to increase action binding as benefits of positive affect on cognition and perception have been reported (e.g. Chiew & Braver, 2011). And as in the second experiment, emotion induction will have no effect on outcome binding as it is not thought to be linked as closely to the dopaminergic system (Tanaka et al., 2019).

Besides vulnerable, grandiose narcissism and substance use history that were already examined in the first study, psychopathy and trait anxiety were added as personality variables for this experiment. For individuals higher on psychopathic traits, increased levels of dopamine have been reported, thus an increased binding would reflect this dopaminergic hyper-activity. Moreover, actions have been reported to be perceived correctly, whereas consequences have not been interpreted adequately in individuals with high psychopathy. Trait Anxiety was expected to be associated with lower binding scores, as this has been shown for state fear. To sum up, reduced binding was expected for vulnerable narcissism, substance history and trait anxiety whereas higher binding was expected for psychopathy. In contrast to effects for emotion induction, we expected changes rather in outcome binding than in action binding, as previous studies have found aberrations in outcome binding and overall binding for personality traits (Hascalovitz & Obhi,

[3] The results presented in this chapter are under review: Render, A., Eisenbarth, H., Oxner, M. & Jansen, P. (under review). Forbidden Temptation—The Influence of Motivational States on Sense of Agency, moderated by Psychopathy and Trait Anxiety.

2015) and we have found alterations in overall binding associated with substance use history in the first study as well. Overall binding and outcome binding are correlated stronger than overall binding and action binding (Tanaka et al., 2019).

The interaction of emotional state and the personality traits narcissism, psychopathy and anxiety on binding were analysed exploratory. On a physiological level, arousal was measured in pupil dilation, skin conductance and heart rate; dopaminergic activity was indexed via blink rates.

6.2 Materials and Methods

This study was preregistered on Open Science Framework (OSF) at the start of data collection (osf.io/pskmh, anonymous link for peer review: https://osf.io/z7spx/?view_only=f30d881f55114285b48972996593b970). The preregistration adheres to the disclosure requirements of OSF. All data, materials, and code used are available on OSF.

6.2.1 Participants

A power analysis calculated with the R package "sjstat" (Lüdecke, 2018) for linear mixed models with one cluster, an effect size of Cohen's $d = 0.9655$ (Christensen et al., 2019) $\eta^2_p=0.189$ for the state fear on action binding), power of 0.95, significance level of $p = 0.05$, and ICC of 0.05, a total sample size of 58 participants was determined. Inclusion criteria were an age ranging between 18 and 35 years as dopamine transporters decrease with age (cut-off 40 years) (Volkow et al., 1996) and vision should not be corrected with glasses (causing glare issues in the eye tracker). In total 59 individuals participated in this study and were pseudo-randomised to one of three emotion inductions considering gender balance. Analyses were conducted on de-identified data. Participants gave information about their age, ranging from 18 to 35 years, $M = 23.75$, $SD = 4.21$, and gender; 26 participants identified as male, 31 as female, 2 as other. Within the different emotion inductions, gender balance was given for the sexual arousal ($N = 21$, $N_f = 10$, $N_m = 11$) and neutral ($N = 20$,

N_f = 9, N_m = 10, N_o=1) condition. The pleasure induction differed in size and had more females than males (N = 18, N_f = 12, N_m = 5, N_o=1).

Ethical approval for the study was obtained from the School of Psychology Human Ethics Committee, by delegated authority of the Victoria University of Wellington Human Ethics Committee (#028117), prior to commencement of any testing activities. Participants were informed about the purpose of the study and gave their written consent prior to participation and received vouchers for their contribution.

6.2.2 Apparatus and Stimuli

The experiment was run on an Acer PC with a 22-in. flat-screen monitor with 1024 × 768 pixel resolution and a 120-Hz refresh rate. Viewing distance was maintained by a chin rest 60 cm from the screen. For this third experiment, the intentional binding task was programmed and run on MATLAB (The MathWorks Inc., 2018) to link the task to the eye tracking and labchart (recording skin conductance and heart rate) software.

6.2.2.1 Intentional Binding Task

In this third experiment each block contained 25 trials and three additional practise trials. Calculation of internal consistency for the intentional binding pre-induction measurement confirms good Cronbach's alpha values of 0.81 for baseline action, 0.79 for baseline outcome, 0.80 for agency action and 0.83 for agency outcome.

6.2.2.2 Pre-test Film Clips

All film clips were pre-tested in an online survey using Qualtrics. Eleven participants rated all three film clips with the affective grid on a scale from 1 to 9 for valence and arousal. The sexually arousing film clip was a threesome scene from the film Love (2015) by Gaspar Noé and was rated M = 6.11 (SD = 2.09) in valence and M = 7.89 (SD = .93) in arousal. The pleasant film clip showed the opening and closing scenes of the film Pride and Prejudice (2005) by Joe Wright, a film clip used in other studies to induce calm but happy states ((Gabert-Quillen et al., 2015) on a scale 1 to

8: calmness (*M* = 6.3, SD = 1.9), happiness (*M* = 4.4 *SD* = 2.4), (Ramzan et al., 2016) on scale of 1 to 5: valence close to 4, arousal close to 1.5)). In our pre-test survey, the film clip was rated *M* = 7.00 (*SD* = 2.18) in valence and *M* = 4.78 (*SD* = 2.28) in arousal. The emotionally neutral film clip was naturalistic footage of a pedestrian street scene, and was rated *M* = 4.36 (*SD* = 1.57) in valence and *M* = 3.64 (*SD* = 3.64) in arousal. A one-way ANOVA confirmed a main effect of valence ($F(2, 26) = 4.851$ $p < .05$ $\eta^2 = .272$), post-hoc tests with Bonferroni correction confirmed that the pleasant film clip ($p = .005$), but only showed a tendency for the sexually arousing film clip compared to the neutral film clip ($p = .055$). Also, a main effect of arousal was found, ($F(2, 26) = 13.62$ $p < .001$ $\eta^2 = .512$), showing higher arousal for the sexually arousing film clip ($p < .001$) compared to the pleasant and neutral film clip. The pleasant and neutral film clips did not differ from one another in arousal ratings ($p = .182$).

6.2.2.3 Emotion Induction

For the main experiment, participants were pseudo-randomly assigned to one of the three emotion inductions, each with one of the three film clips that were pre-tested to induce an emotional state. The sexually arousing film clip showed a threesome scene, the pleasant film clip showed scenery of nature and a calm romantic interaction, and the emotionally neutral film clip was a naturalistic footage of a pedestrian street scene.

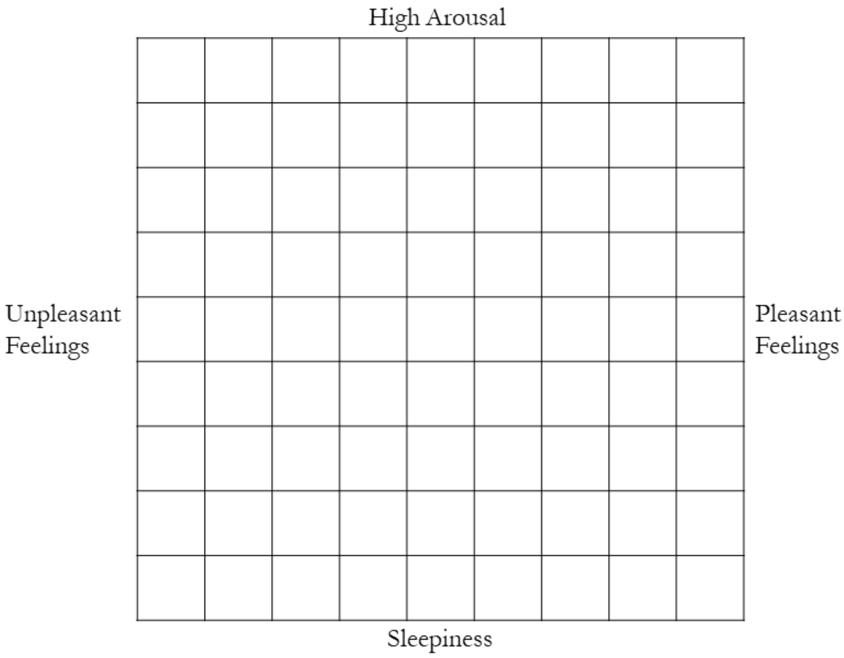
As in the second study, still images taken from the corresponding film clip were presented between trials for 500ms to maintain the arousal and pleasure while testing in addition to showing the film clips. In the second study, effects for inter-trial images did not show differences between two emotionally neutral inductions, with and without inter-trial images.

6.2.2.4 Affective Grid

The affective grid (Russell et al., 1989) consists of two dimensions valence and arousal on scales from 1 to 9. Participants use one cross for both axes simultaneously to describe their current feelings.

Figure 6

Adapted version of the Affective Grid by Russell et al. (1989)



6.2.3 Questionnaires

6.2.3.1 Substance Use History

Questions for frequency of substance use were extracted from the validated questionnaire of the European School Survey Project on Alcohol and Other Drugs (Kraus et al., 2016) as follows: On how many occasions (if any) have you used [insert substance]? The answer is split in two scales with seven possible categories (0, 1-2, 3-5, 6-9, 10-19, 20-39, 40 and more) for (a) in your lifetime, (b) during the last 12 months. Focus of substance were cannabis, amphetamine, methamphetamine, tranquilizers or sedatives, ecstasy, cocaine, LSD, ketamine, psilocybin, heroin, GHB or GBL. Sum scores for the number of different substances consumed in lifetime and during the last 12 months were calculated.

6.2.3.2 Narcissism

Vulnerable narcissism was measured with the Pathological Narcissism Inventory (PNI) (Pincus et al., 2009). The full version contains 52 items on a scale ranging from 1 (not at all like me) to 6 (very much like me). Evidence for validity and reliability is given (Cronbach's Alpha r = 0.77) (Jakšić et al., 2014); Cronbach's α in this sample was r = .91. The PNI was proposed as a measurement for both subtypes, narcissistic grandiosity (entitlement rage, exploitativeness, grandiose fantasy, self-sacrificing self-enhancement) and narcissistic vulnerability (contingent self-esteem, hiding the self, devaluing). Since factor analysis indicated that only one subscale (exploitativeness) represents the grandiose subtype (J. D. Miller et al., 2011), we used it to assess the vulnerable type only (40 Items) excluding the subscale exploitativeness and grandiose fantasies (loads on both factors alike).

Grandiose narcissism was assessed with the NPI-16, a short version of the NPI 40-item self-report assessment of trait narcissism (Raskin & Terry, 1988). The original NPI has four factors: Leadership/Authority, Superiority/Arrogance, Self-Absorption/Self-Admiration, and Entitlement/Exploitation. Reliability and validity have been confirmed in general (Kubarych et al., 2004; Raskin & Terry, 1988) and in this sample Cronbach's α r = .74. However, in accordance with (J. D. Miller et al., 2011) we only used 16 items loading on the two factors Leadership/Authority and Exhibitionism/Entitlement in this study. Factor analyses (Corry et al., 2008; Kubarych et al., 2004) showed a better replicability for these factors than other factor structures based on the NPI.

6.2.3.3 Psychopathy

The PPI-R-40 (Eisenbarth et al., 2015), an abbreviated measure (using a genetic algorithm) for the PPI (Lilienfeld & Andrews, 1996) and PPI-R (154 Items) (Lilienfeld & Widows, 2005) was used to measure psychopathy. The 40 items of the PPI-R-40 load on the subscales coldheartedness, fearless dominance and self-centred impulsivity. Responses were given on a four-point scale (false, mostly false, mostly true, true). To screen for manipulative tendencies, two validity scales were included: virtuous responding and deviant responding (Kelley et al., 2016). The PPI-R-40 shows good reliability generally and in this sample (both Cronbach's α $r = .8$), demonstrates appropriate convergence with the full-length version (rs > .75) and the scales also show comparable criterion validity coefficients for measures of personality and externalizing behaviour (Eisenbarth et al., 2015; Ruchensky et al., 2017).

6.2.3.4 Trait Anxiety

The State-Trait Anxiety Inventory (STAI) is an established, reliable, and brief self-report scale for assessing state and trait anxiety in research and clinical practice (Spielberger, 1983). In this study, only the 20-item trait anxiety scale was used to measure individual differences in anxiety proneness as a personality trait. Responses to items required subjects to indicate how they generally feel by reporting how often they have experienced anxiety-related feelings and cognitions on a four-point scale with almost never, sometimes, often and almost always. Cronbach's α in this sample was $r = .93$

6.2.4 Physiological Measurements

6.2.4.1 Pupillometry and Spontaneous Eye Blink Rates

Area of the right pupil (in arbitrary units) was recorded using an EyeLink 1000-Plus desktop mounted eye-tracker (SR Research Ltd., Mississauga, ON) using a 250-Hz sampling rate. Participants were tested in a dimly lit room. Two nine-point calibrations and validations of the eye tracker were performed at the beginning of the session. Before each trial, a manual drift check was performed, and if necessary, the calibration and validation were performed again.

6.2.4.2 Skin Conductance and Heart Rate

Skin conductance and heart rate were collected via ADInstrument bioamps and converted from analogue to digital signals by ADInstruments Powerlab 16/30 and then recorded in LabChart 8.0.1. All physiological measures were collected and analysed following established guidelines, for skin conductance (Boucsein, 2012) and for heart rate (Jennings et al., 1981).

Skin conductance was recorded from the medial phalanges of the index and ring fingers using ADInstruments bipolar dry stainless steel GSR electrodes (MLT116F) and a ML116 AC GSR Amp with a sampling rate of 1 kHz. Responses were measured in micro-Siemens (μS).

Heart rate was measured via electrocardiography (ECG) using disposable adhesive silver/silver chloride (Ag/AgCl) ECG electrodes placed underneath the right collarbone and lower left ribcage, referenced to the left side underneath the collarbone. The ECG signal was amplified by ADInstruments ML138 Octal Bio Amp, sampled at 1 kHz and band-pass filtered offline between 1 Hz and 400 Hz. Data from two participants was excluded from heart rate analysis due to technical issues during recording.

6.2.5 Procedure and Experimental Design

The study took place at the Victoria University of Wellington; the duration was between 1.5-2 hours. After providing informed consent, participants' baseline heart rates and skin conductance were recorded, and eye tracking calibration was performed. Sessions started with a 3-minute baseline measure of blink rates as commonly performed in other studies (Abusharha, 2017; Maffei & Angrilli, 2018). This was followed by the first of four mood ratings (before and after each intentional binding task) on the affective grid (Russell et al., 1989). After completing the first four intentional binding blocks (pre-emotion induction) and a second mood rating, participants took a short break (between 5 and 10 minutes). After the break and another eye calibration, participants watched one of the three film clips. After a third mood rating, they completed a second set of four intentional binding blocks (post-emotion induction) and fourth mood rating on the affective grid. Questionnaires were completed online after the computer-based tasks using the Sosci-survey platform. Duration for completing the questionnaires was 15-20 minutes on average.

6.2.6 Data Pre-processing

6.2.6.1 Pupillometry and Spontaneous Eye Blink Rates

Pupil data were pre-processed with the gazer package (Geller, 2019) in R. Pupil data were de-blinked (blinks identified, removed and interpolated during the blink period and across a longer segment that extends before and after the blink). Blinks were identified by the blink column with 0s or 1s denoting absence or presence of a blink provided by EyeLink 100ms before and after the blink were eliminated as generally recommended. Time windows around blinks were extended with interpolation, starting 100-200ms before and after the blink (Nyström et al., 2016) thereby eliminating spurious samples caused by the closing and opening of the eyelids. Missing data from blinks and failure for pupil size were reconstructed by using a linear interpolation (Bradley et al., 2008). Smoothing was done with 5-point moving average. Subtractive baseline correction was conducted to control for variability in overall pupil size arising from non-task related (tonic) state of arousal (Zekveld et al., 2018). Specifically, median pupil size during the baseline period 0 to 100ms after each trial onset was calculated (Mathôt et al., 2018). For subjects and items whose amount of missing data was above the threshold of 20% (Winn et al., 2018) artefact rejection was performed, also spurious pupil values, so pupil values considered too small and too large were removed from the data (Mathôt et al., 2018; Winn et al., 2018) by visual inspection in histograms (Mathôt, 2018). A second pass was performed in addition to interpolation to guarantee that the data is not still contaminated by rapid pupil size disturbances with a median absolute deviation (Kret & Sjak-Shie, 2019). Lastly, data were down sampled and aggregated per trial.

For spontaneous eye blink rate, blinks identified by EyeLink were used. Rates per minute within a trial were calculated.

6.2.6.2 Change in Skin Conductance and Heart Rate

Skin conductance was operationalized as the peak activity during each trial (maximum values), relative to average baseline activity measured across the 500ms prior to trial onset. Heart rate was calculated by subtracting the mean of the baseline (interval 500ms prior to each trial onset) from the mean value of each trial.

6.2.7 Data exclusion criteria

Artefacts defined as values less than 40 and more than 150 for heart rate and artefacts ceiling effects for skin conductance (out of range) were removed. One participant reported to have mixed up two blocks of the intentional binding experiment, so that the corresponding action binding score was not used in the analysis.

6.2.8 Statistical Analysis

Intentional Binding was calculated the same way as in the first and second experiment. Again, a higher binding score refers to a smaller interval in perception between key press and tone.

Emotion manipulation (emotion induction) was checked with mixed ANOVAs with the within factor “time” and the between factor “group” for the arousal and valence ratings before and after the film clips. For physical arousal during the film clips, mixed ANOVAs with between factor “film clip” and within factor “interval” for pupil dilation, skin conductance, and heart rate were performed. A linear mixed model predicting the subjective arousal after each binding task (post-arousal rating) included the interaction of time * group and the main effects, pre-arousal, pupil, skin conductance, heart rate as fixed effects and participants as random intercept.

To analyse effects of emotion induction on binding, two mixed linear models were conducted for each binding component with participant as random intercept. The first model included pre-affective ratings as main effects to control for differences at baseline; the second model additionally considered the interaction of blinks * time * group to examine dopaminergic activity. As number of observations on which models are fitted differ, model comparisons cannot be provided.

Six one-way ANOVAs with between subject factor "group" and within subject factor "participant" for age, substance use history, grandiose narcissism, vulnerable narcissism, psychopathy and trait anxiety were conducted to check whether groups differ in these characteristics. For interactive effects of personality and emotional state, four different models focusing on the interaction of substance use history/vulnerable narcissism/trait anxiety/psychopathy * time * group, and blinks * time * group were run exploratory for each binding component.

6.3 Results

6.3.1 Manipulation Check

6.3.1.1 Self-report: Affective Grid

Two two-way mixed ANOVAs with within-subjects factor "time" and between-subjects factor "group" for subjective ratings before and after the film clip were conducted to check if emotion manipulation (emotion inductions) was successful. Analysis of arousal ratings displayed an interaction of time * group and a main effect of time (group * time $F(2,112) = 6.620$, $p < .01$ $\eta^2 = 0.084$, time $F(1,112) = 28.115$, $p < .001$ $\eta^2 = 0.179$, group $F(2,112) = 1.676$, $p = .192$ $\eta^2 = 0.021$) confirming that sexual arousal induction was successful with higher subjective arousal after watching the sexual arousing film clip than before, and higher post-arousal ratings compared to the pleasant and neutral group. For valence, a main effect of time was revealed with higher valence ratings after all three film clips; but no interactive effect of time and group in valence (group * time $F(2,112) = 0.790$ $p = .456$ $\eta^2 = 0.011$, time $F(1,112) = 25.816$ $p < .001$ $\eta^2 = 0.185$, group $F(2,112) = .176$ $p = .838$ $\eta^2 = 0.003$. Thus, we did not find specific effects in valence for the pleasant film clip compared to the sexually arousing or the neutral films (mean values and SD in table 14).

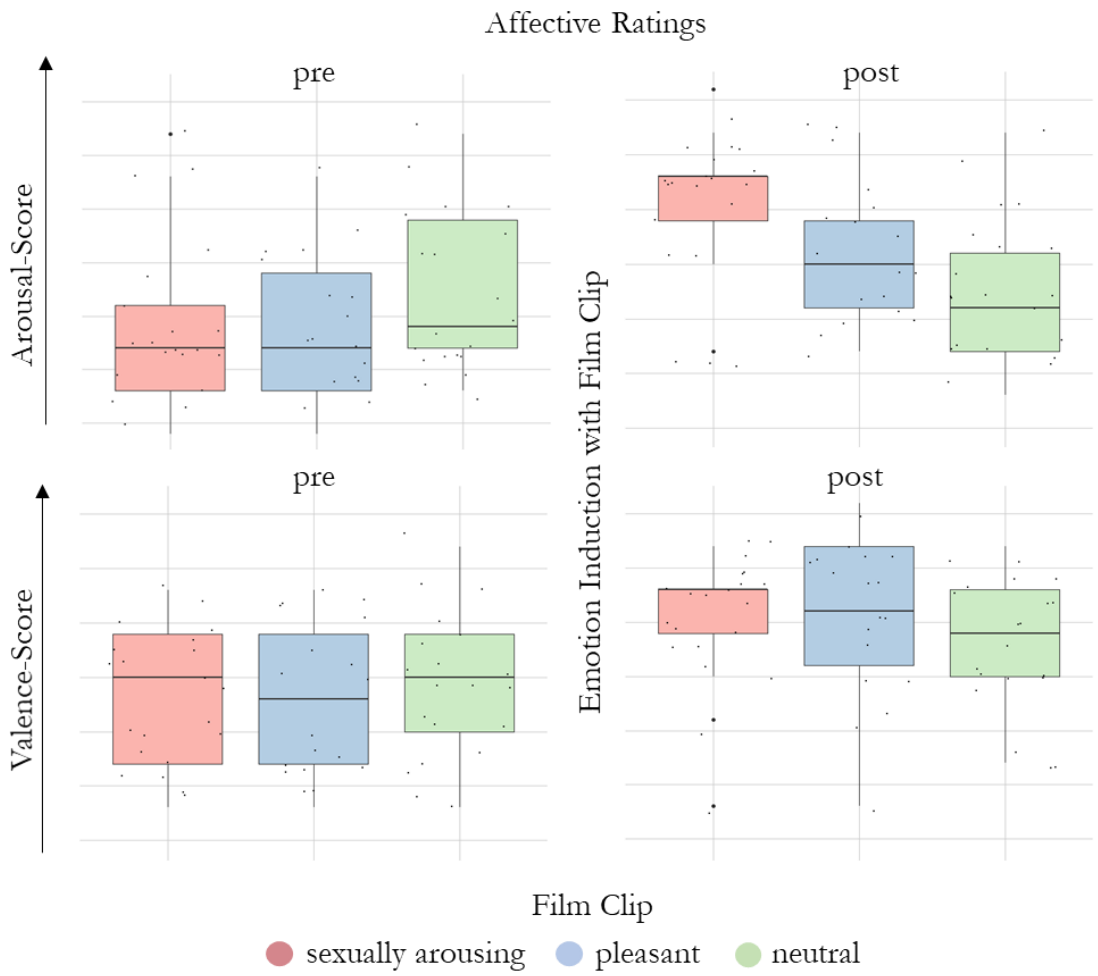
Table 14

Means and standard deviations for emotion ratings by film clip and time.

		Intentional Binding Task			
Film clip		Pre-film clip		Post-fil clip	
		Pre-measure	*Post-measure*	*Pre- measure*	*Post-measure*
Neutral	Arousal	4.60 (1.32)	4.20 (1.75)	4.40 (1.53)	3.45 (2.04)
	Valence	5.45 (1.43)	4.75 (1.61)	5.75 (1.51)	4.55 (1.75)
Pleasure	Arousal	4.56 (1.34)	3.50 (1.57)	5.34 (1.60)	3.56 (1.74)
	Valence	5.33 (1.56)	4.50 (1.77)	6.33 (1.76)	4.72 (1.85)
Sexual Arousal	Arousal	4.24 (1.63)	3.48 (1.87)	6.43 (1.44)	4.29 (1.50)
	Valence	5.52 (1.68)	4.57 (2.23)	6.33 (1.39)	4.95 (1.65)

Figure 7

Affective ratings on the affective grid before and after the film clip by group.



6.3.1.2 Psychophysiology during Film Clips

Psychophysiology was assessed in three equal intervals during the film clips: beginning, middle part and end. Three two-way mixed ANOVAs with between-subjects factor "film clip" and within-subjects factor "interval" for pupillometry, skin conductance and heart rate were conducted.

6.3.1.2.1 Pupillometry

Results for pupillometry confirmed a main effect for emotion induction with film clips ($F(2, 56) = 93.71$ $p < .001$ $\eta^2 = 0.743$, sexually arousing $M = 1440.67$ $SD = 641.30$, pleasant $M = -90.91$ $SD = 295.86$, neutral $M = -343.53$ $SD = 400.76$. Post-hoc tests with Bonferroni correction confirmed that all differences were significant (all p's $< .016$) showing that the sexual arousing film clip caused the highest pupil dilation hence greatest arousal, followed by the pleasant film clip. For the main effect of interval (F(2, 112) = 20.34 p < .001 η^2 = 0.006), no significant differences can be reported after Bonferroni correction (all p's > .05, beginning M = 359.72 SD = 826.04, middle M = 464.14 SD = 969.49, end M = 281.92 SD = 1006.65)—there were no differences in level of arousal between the three different intervals of the film clips. The interaction between film clip * interval was also significant (F(4, 112) = 18.34 p < .001 η^2 = 0.012).

6.3.1.2.2 Skin Conductance

Results for skin conductance confirmed a main effect for emotion induction (F(2, 152) = 2.998 p = .05 η^2 = 0.033, sexually arousing M = 1.80 SD = 2.40, pleasant M = 0.87 SD = 2.55, neutral M = 0.95 SD = 1.98). However, post-hoc test with Bonferroni correction rejected that differences between film clips were significant (all p's > .12). For the main effect of interval (F(2, 152) = 8.731 p < .001 η^2 = 0.096), significant differences can be reported between the beginning and middle part (p < .001), but differences between the beginning and end, and middle part and end were not significant (all p's > .05, beginning M = 2.08 SD = 2.12, middle M = 0.31 SD = 2.42, end M = 1.33 SD = 2.19). The interaction between film clip * interval was also not significant (F(4, 152) = 1.339 p = .26 η^2 = 0.029). Skin conductance increased most during the first interval (beginning) in all three film clips.

6.3.1.2.3 Heart Rate

Main effect of emotion induction for heart rate was not significant (F(2, 167) = 0.320 p = .73 η^2 = 0.003). For the main effect of interval (F(2, 167) = 27.54 p < .001 η^2 = 0.244), significant differences can be reported between beginning and middle part (p < .001), and beginning and end (p < .001) but not between middle part and end (p = .31, beginning M = -3.89 SD = 6.78, middle M = 1.95 SD = 2.92, end M = 0.61 SD = 2.16). The interaction between film clip * interval was not significant (F(4, 167) = 0.631 p = .64 η^2 = 0.011).

6.3.1.2.4 Self-report Arousal Model

To evaluate if arousal levels were maintained during the task, post-affective ratings (after each binding task) were predicted by physiological arousal measures in a linear mixed model, with fixed effects for time * group, pre-arousal, pupil, skin conductance, heart rate and participant as random intercept. Results showed significant effects for time, pre-arousal, pupil, skin conductance, heart rate and interactive effects for time * group (table 15). The physiological arousal measures pupil dilation, skin conductance and heart rate during the task predicted self-rating for arousal after the binding task.

Table 15

Linear mixed model for post-arousal rating and psychophysiology measures.

*Fixed effects: Time * group, pre-arousal, pupil, skin conductance, heart rate and random intercept participant (N = 56).*

Variable	Estimate	*SE*	*p*	95% CI
Intercept	3.920	0.390	<.001	3.143, 4.699
Time	-1.062	0.029	<.001	-1.119, -1.005
Pre-arousal	0.072	0.009	<.001	0.054, 0.091
Pupil	0.000	0.000	<.001	0.000, 0.000
Skin Conductance	0.018	0.004	<.001	0.009, 0.027
Heart Rate	-0.005	0.002	<.001	-0.009, -0.002
Pleasure Group * Time	1.742	0.046	<.001	0.897, 1.064
Sexual Arousal Group * Time	0.981	0.042	<.001	1.651, 1.832
Nonsignificant				
Pleasure Group	-0.771	0.549	.165	-1.866, 0.323
Sexual Arousal Group	-0.748	0.535	.168	-1.814, 0.319

6.3.2 Main Analysis

6.3.2.1 Influence of Emotional States on Binding

To analyse effects of emotion induction on binding, two mixed linear models were conducted for each binding component. The first model included pre-affective ratings as main effects only, the second model additionally considered the interaction of blinks* time *group. As number of observations on which models are fitted differ, model comparisons cannot be provided.

6.3.2.1.1 Action Binding

Both models for action binding confirmed significant effects for the pre-valence ratings indicating that higher valence ratings were associated with reduced binding independent of emotion induction. Both models also showed significant interaction effects for the sexual arousal group * time confirming that the sexually arousing film clip evoked a decrease in mean action binding, in line with our hypothesis. The pre-affect model showed a significant main effect of time (stronger binding after all emotion inductions independent of content) and an interaction of pleasure group * time (table 16). This interaction indicates that the pleasure induction lead to maintained action binding level. The neutral induction whereas caused an increase, which was not predicted in the hypotheses (table 17). The main effect of time and the interaction of pleasure group * time disappeared, when the interaction of blinks * time * condition was included in the model. Instead, the main effect of pre-arousal ratings reached significance indicating that higher pre-arousal was associated with lower action binding.

Effects for blinks, time * blinks, pleasure group * blinks, time * pleasure group * blinks, sexual arousal group * blinks, time, sexual arousal group * blinks were significant underlining the relevance of dopaminergic activity for action binding.

Table 16

Linear mixed models for action binding.

Pre-affective ratings model.

*Fixed effects: Time * group, pre-arousal, pre-valence and participants as random intercept (N = 59, number of observations = 11700)*

Pre-affective ratings model with blinks.

*Fixed effects: Time * group, pre-arousal, pre-valence, blinks * time * group and participants as random intercept (N = 59, number of observations = 11676)*

Variable	Estimate	*SE*	*p*	95% CI	Estimate	*SE*	*p*	95% CI
	Pre-affect				Pre-affect and Blinks			
Intercept	0.044	0.010	<.001	0.024, 0.064	0.033	0.010	<.01	0.013, 0.053
Time	0.024	0.001	<.001	0.021, 0.026	0.001	0.001	.314	-0.001, 0.004
Pre-arousal	0.001	0.000	.119	-0.000, 0.001	0.002	0.000	<.001	0.002, 0.003
Pre-valence	-0.006	0.000	<.001	-0.007, -0.005	-0.005	0.000	<.001	-0.006, -0.004
Pleasure Group * Time	-0.016	0.001	<.001	-0.020, -0.013	-0.001	0.002	.779	-0.005, 0.004
Sexual Arousal Group * Time	-0.038	0.001	<.001	-0.042, -0.034	-0.018	0.002	<.001	-0.022, -0.013
Blinks					-0.000	0.000	<.01	-0.000, -0.000
Time * Blinks					0.002	0.000	<.001	0.002, 0.002
Pleasure Group * Blinks					-0.000	0.000	<.01	-0.001, -0.000
Time * Pleasure Group * Blinks					-0.001	0.000	<.001	-0.002, -0.001
Sexual Arousal Group * Blinks					0.001	0.000	<.001	0.000, 0.000
Time * Sexual Arousal Group * Blinks					-0.002	0.000	<.001	-0.002, -0.002

Nonsignificant								
Pleasure Group	0.023	0.014	.111	-0.005, 0.051	0.026	0.014	.066	-0.002, 0.053
Sexual Arousal Group	0.021	0.014	.127	-0.006, 0.048	0.014	0.014	.281	-0.012, 0.041

Table 17

Binding means and standard deviations by group.

		Pre-measure	Post-measure
Group	Binding	*M (SD)*	*M (SD)*
Neutral	action	14.50 (38.27)	36.15 (68.51)
	outcome	94.54 (72.26)	97.56 (105.20)
	overall	109.04 (95.63)	133.71 (115.46)
Pleasure	action	36.88 (78.76)	39.62 (49.40)
	outcome	151.03 (83.24)	148.79 (90.86)
	overall	213.49 (127.70)	188.40 (88.76)
Sexual Arousal	action	34.81 (51.52)	17.09 (47.66)
	outcome	94.84 (116.98)	83.44 (103.18)
	overall	129.66 (136.77)	100.52 (118.79)

6.3.2.1.2 Outcome Binding

Both models for outcome binding showed significant effects for the pre-arousal ratings, thus, higher arousal was associated with lower outcome binding independent of emotion induction. The interaction of sexual arousal group * time was significant in both models revealing that the sexually arousing film clip evoked a decrease in mean outcome binding, which was not predicted. The pre-affect model showed a significant main effect of the pleasure group which demonstrates that the participants of the pleasure group had higher outcome binding independent of time of measurement (pre- and post- emotion induction). This effect disappeared when the interaction of blinks * time * condition was included in the model. In the blinks model, a main effect of time was observed showing stronger binding after all emotion inductions independent of content.

Effects for blinks, time * blinks, sexual arousal group * blinks, time * sexual arousal group * blinks were significant, but effects of pleasure group * blinks, time * pleasure group * blinks did not reach significance, indicating that effects of dopaminergic activity are present in outcome binding but might be more pronounced in action binding (table 18).

Table 18

Linear mixed models for outcome binding.

Pre-affective ratings model.

*Fixed effects: Time * group, pre-arousal, pre-valence and participants as random intercept (N = 59, number of observations = 11700)*

Pre-affective ratings model with blinks.

*Fixed effects: Time * group, pre-arousal, pre-valence, blinks * time * group and participants as random intercept (N = 59, number of observations = 11676).*

Variable	Estimate	*SE*	*p*	95% CI	Estimate	*SE*	*p*	95% CI
	Pre-affect				Pre-affect and Blinks			
Intercept	0.115	0.019	<.001	0.077, 0.154	0.115	0.020	<.001	0.076, 0.154
Time	0.002	0.001	.073	-0.000, 0.005	-0.005	0.002	<.01	-0.009, -0.002
Pre-arousal	-0.004	0.000	<.001	-0.005, - 0.003	-0.003	0.000	<.001	-0.004, -0.002
Pleasure Group	0.056	0.028	<.05	0.001, 0.112	0.053	0.028	.061	-0.002, 0.109
Sexual Arousal Group * Time	-0.050	0.002	<.05	-0.009, - 0.001	0.015	0.003	<.001	0.009, 0.020
Blinks					-0.000	0.000	<.01	-0.001, -0.000

Time * Blinks					0.001	0.000	<.001	0.000, 0.001
Sexual Arousal Group * Blinks					0.001	0.000	<.001	0.001, 0.001
Time * Sexual Arousal Group * Blinks					-0.002	0.000	<.001	-0.002, -0.001
Nonsignificant								
Pre-valence	-0.001	0.000	.205	-0.002, 0.000	-0.001	0.000	.249	-0.002, 0.000
Sexual Arousal Group	-0.001	0.027	.970	-0.054, 0.052	-0.010	0.027	.705	-0.064, 0.0433
Pleasure Group * Time	-0.001	0.002	.585	-0.005, 0.003	-0.003	0.003	.221	-0.009, 0.002
Pleasure Group * Blinks					0.000	0.000	.103	-0.000, 0.001
Time * Pleasure Group * Blinks					0.003	0.000	.146	-0.000, 0.001

6.3.2.2 Personality characteristics

Six one-way ANOVAs with between subject factor "group" and within subject factor "participant" for age, substance use history (lifetime), grandiose narcissism, vulnerable narcissism, psychopathy and trait anxiety confirmed, that the three groups only differ in age and grandiose narcissism but not in substance use history (lifetime), vulnerable narcissism, psychopathy and trait anxiety (table 19). Grandiose narcissism will therefore not be in included in analyses.

Table 19

Mean, SD and group comparison for age, psychopathy score and trait anxiety score by group.

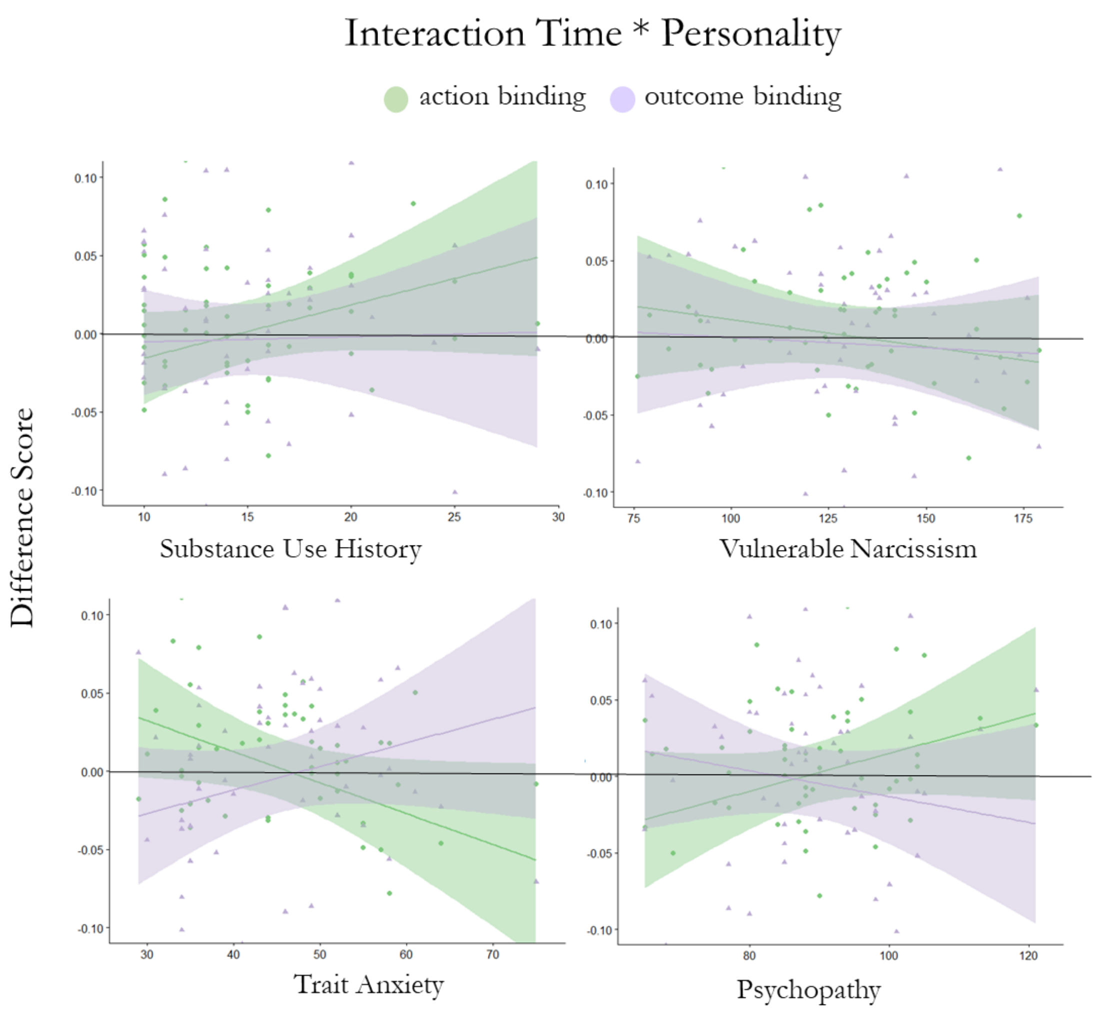
Variable	Group			Group comparison	
	Sexual arousal	pleasure	neutral	$F(2,56)$	p
Age	24.81(5.15)	24.06(3.23)	22.35(3.57)	3.771	<.05
Substance Use History	14.90(3.59)	13.89(3.56)	16.10(6.08)	1.110	.337
Grandiose Narcissism	3.48(2.79)	2.33(2.22)	4.70(3.36)	3.285	<.05
Vulnerable Narcissism	137.33(27.93)	123.28(25.65)	125.45(21.92)	1.793	.176
Psychopathy	89.81(11.09)	83.94(10.31)	92.35(12.76)	2.584	.085
Trait Anxiety	46.67(11.32)	45.89(8.36)	43.80(9.40)	0.447	.642

6.3.2.2.1 Effects of Personality and Substance Use History on Binding

Only significant predictors from the emotion induction models above were included in the linear mixed models: Action binding models included pre-valence and pre-arousal, outcome binding models only pre-arousal. All models included the interaction of blinks * time * group as an indicator of dopaminergic activity.

Figure 8

Differences scores for binding (post – pre) by binding component for personality traits and substance use history. Above 0 = increase in binding from pre- to post-measurement, below 0 = decrease in binding from pre- to post-measurement.



6.3.2.2.2 Interaction of Emotion Induction, Time and Substance Use History on Binding

The model taking substance use history into account confirmed significant effects for affective ratings (pre-arousal and pre-valence) on action binding. Although no main effect of substance use history was found, a significant interaction of substance use history * time was observed showing an increase in action binding over time in individuals with more substance use history (figure 8). The pleasure group showed higher action binding than the other two groups in both measurements. The pleasure group also showed interactive effects with time confirming effects of the pleasant film clip and with substance use history. The interaction of substance use history * pleasure group * time indicates that substance use history leads to a different reaction to the pleasant film clip. In contrast to the other models, the effects of sexual arousal induction disappeared, nor was an interaction for sexual arousal group * time * substance use history observed (table 20).

The model for outcome binding confirms an influence of pre-arousal on outcome binding independent of time of measurement. Both emotion inductions caused significant effects (interaction sexual arousal group * time, pleasure group * time) and emotional inductions interacted with substance use history (figure 9). Blinks showed stronger effects for action binding than for outcome binding.

Figure 9

Change in action and outcome binding between pre- and post-induction task by group (difference score, post-pre) for substance use history. Above 0 = increase in binding from pre- to post-measurement, below 0 = decrease in binding from pre- to post-measurement.

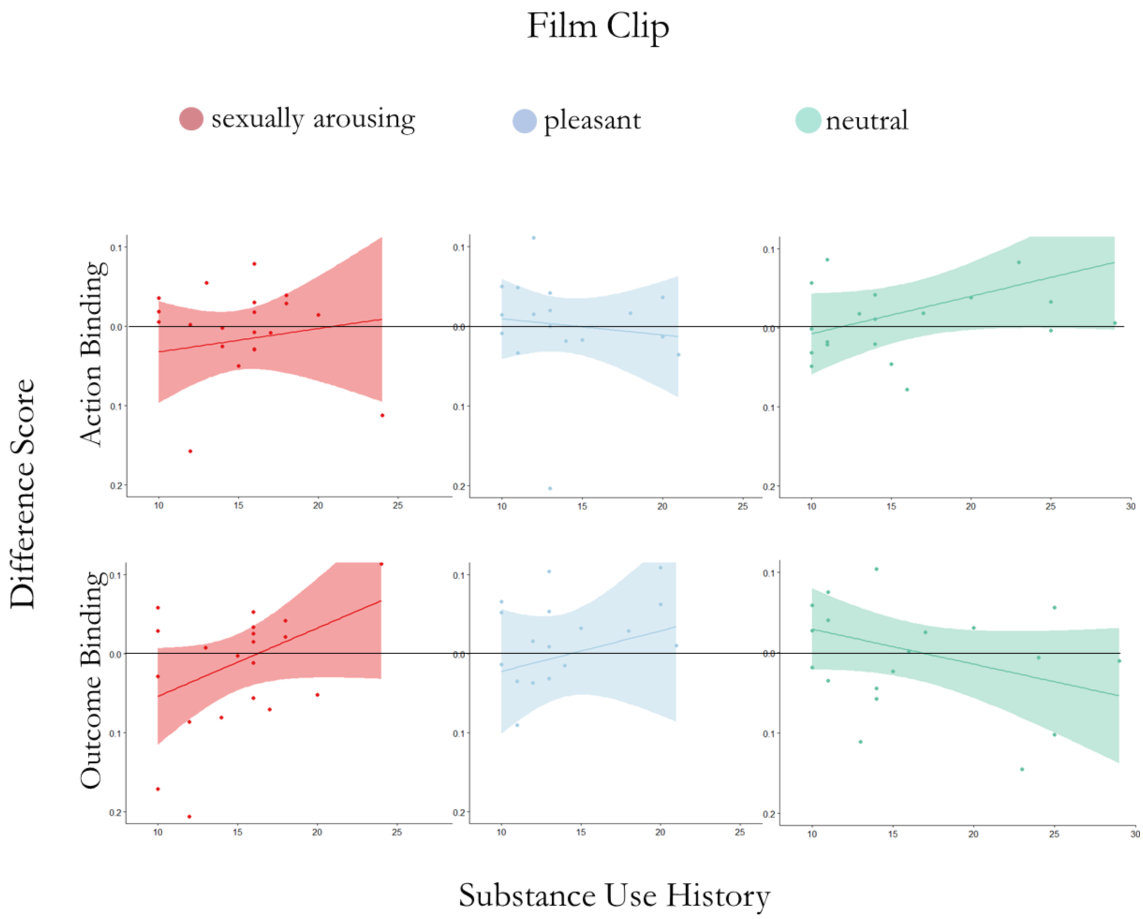


Figure 9 displays the interactive effects of emotion inductions and substance use history (lifetime). Although no interactive effects for sexual arousal group * time * substance use history were found for action binding, significant effects were revealed for outcome binding showing that individuals who have consumed more substances or have reported a higher frequency of consume show increased outcome binding when sexually aroused. Reversed effects can be observed for individuals with low or no substance use history, outcome binding is decreased in sexual arousal.

While the pleasant film clip shows a similar, but less pronounced effect than sexual arousal for outcome binding, the emotional neutral film clip displays the reversed pattern: Individuals with little or no substance use history benefit from the neutral induction, individuals with great substance use history show reduced binding after watching the neutral film clip.

Since main effects for the pleasure group and interactive effects for pleasure group * substance use history were found for action binding, interactive effects between pleasure group * time * substance use history remain difficult to interpret.

Table 20

Linear mixed models for action binding and outcome binding.

*Fixed effects: Time * group * substance use history, pre-valence, pre-arousal, blinks * time * group and participants as random intercept (N = 59, number of observations = 11676 action binding, = 11776 outcome binding).*

Variable	Estimate	*SE*	*p*	*95% CI*
Action Binding Model				
Intercept	0.043	0.026	.102	-0.009, 0.095
Time	-0.070	0.003	<.001	-0.077, -0.063
Pre-arousal	0.004	0.000	<.001	0.003, 0.005
Pre-valence	-0.003	0.000	<.001	-0.004, -0.003
Pleasure Group	-0.104	0.047	<.05	-0.198, -0.011
Pleasure Group * Time	0.109	0.006	<.001	0.097, 0.120
Substance Use History * Time	0.004	0.000	<.001	0.004, 0.005
Substance Use History * Pleasure Group	0.009	0.003	<.01	0.0027, 0.015
Substance Use History * Pleasure Group * Time	-0.007	0.000	<.001	-0.008, -0.007
Blinks	-0.001	0.000	<.001	-0.001, -0.000
Time * Blinks	0.002	0.000	<.001	0.002, 0.002

Pleasure Group * Time * Blinks	-0.001	0.000	<.001	-0.002, -0.001
Sexual Arousal Group * Blinks	0.001	0.000	<.001	0.001, 0.001
Sexual Arousal Group * Time * Blinks	-0.002	0.000	<.001	-0.002, -0.002
Nonsignificant				
Sexual Arousal Group	0.038	0.046	.421	-0.055, 0.130
Sexual Arousal Group * Time	-0.009	0.006	.177	-0.021, 0.004
Substance Use History	-0.001	0.002	.388	-0.004, 0.002
Substance Use History * Sexual Arousal Group	-0.002	0.003	.534	-0.008, 0.004
Substance Use History * Sexual Arousal Group * Time	-0.001	0.000	.126	-0.001, 0.000
Pleasure Group * Blinks	-0.000	0.000	.901	-0.000, 0.000
Outcome Binding Model				
Intercept	0.147	0.054	<.01	0.040, 0.254
Time	0.068	0.004	<.001	0.061, 0.076
Pre-arousal	-0.003	0.000	<.001	-0.004, -0.002
Pleasure Group * Time	-0.143	0.007	<.001	-0.157, -0.130
Sexual Arousal Group * Time	-0.186	0.007	<.001	-0.200, -0.172
Substance Use History * Time	-0.005	0.000	<.001	-0.005, -0.004
Substance Use History * Pleasure Group * Time	0.009	0.000	<.001	0.008, 0.010
Substance Use History * Sexual Arousal Group * Time	0.013	0.000	<.001	0.012, 0.013
Time * Blinks	0.001	0.000	<.001	0.000, 0.000
Sexual Arousal Group * Blinks	0.000	0.000	<.05	0.000, 0.001
Sexual Arousal Group * Time * Blinks	-0.001	0.000	<.001	-0.001, -0.001

Nonsignificant				
Pleasure Group	0.114	0.097	.242	-0.078, 0.307
Sexual Arousal Group	0.124	0.095	.199	-0.066, 0.314
Substance Use History	-0.003	0.003	.425	-0.009, 0.004
Substance Use History * Pleasure Group	-0.005	0.006	.483	-0.017, 0.008
Substance Use History * Sexual Arousal Group	-0.009	0.006	.146	-0.021, 0.003
Blinks	0.000	0.000	.961	-0.000, 0.000
Pleasure Group * Blinks	-0.000	0.000	.805	-0.000, 0.000
Pleasure Group * Time * Blinks	0.000	0.000	.216	-0.000, 0.001

6.3.2.2.3 Interaction of Emotion Induction, Time and Vulnerable Narcissism on Binding

Linear mixed models taking the interaction of emotional states * vulnerable narcissism into account, confirmed the effects of both emotion inductions on action and outcome binding (sexual arousal group * time, pleasure group * time). However, the model did not reveal the predicted main effect of vulnerable narcissism on action nor outcome binding. However, we found an interaction of time * vulnerable narcissism showing a reduction in both binding components over time (Figure 8). Moreover, we observed significant effects in action and outcome binding for psychopathy * sexual arousal group * time as well as psychopathy * pleasure group * time. Both dimensions of the affective ratings, pre-arousal and pre-valence, had significant main effects on action binding. Pre-arousal was also significant for outcome binding; effects of blinks hence dopaminergic activity were slightly more pronounced for action binding than for outcome binding (table 21).

Figure 10

Change in action and outcome binding between pre- and post-induction task by group (difference score, post-pre) for vulnerable narcissism. Above 0 = increase in binding from pre- to post-measurement, below 0 = decrease in binding from pre- to post-measurement.

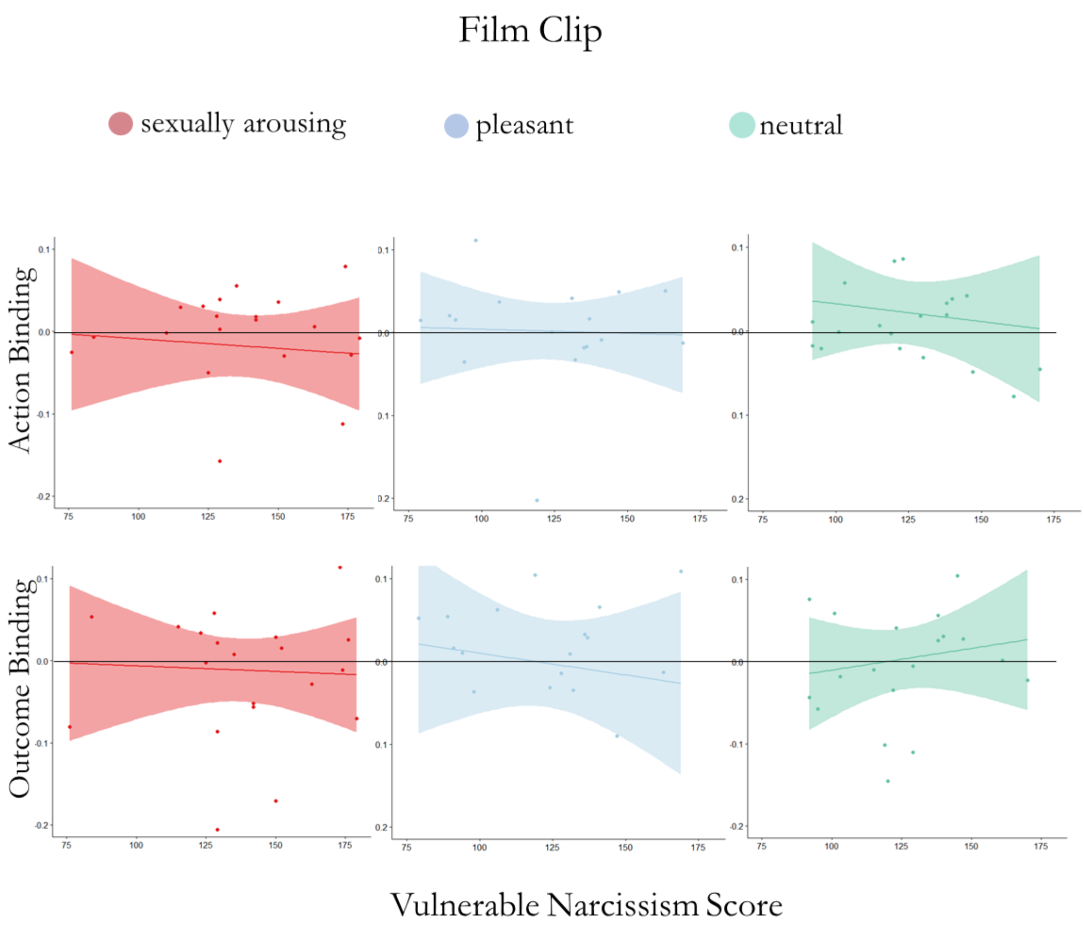


Figure 10 shows a decrease in both binding components in sexual arousal for individuals with higher vulnerable narcissism, whereas binding seems to be intact in people with lower vulnerable narcissism when sexually aroused. The pleasant induction did not induce changes in action, independent of vulnerable narcissism and the neutral film clip led to an increase in action binding for participants with low scores on vulnerable narcissism, whereas participants with high scores in this variable did not benefit from it. Outcome binding was reduced after the pleasant film clip and increased after the neutral film clip for higher vulnerable narcissism, effects were reversed for individuals with lower vulnerable narcissism.

Table 21

Linear mixed models for action binding and outcome binding.

*Fixed effects: Time * group * vulnerable narcissism, pre-valence, pre-arousal, blinks * time * group and participants as random intercept (N = 59, number of observations = 11676 action binding, = 11776 outcome binding).*

Variable	Estimate	*SE*	*p*	*95% CI*
Action Binding Model				
Intercept	0.023	0.056	.688	-0.089, 0.134
Time	0.097	0.007	<.001	0.084, 0.110
Pre-arousal	0.003	0.004	<.001	0.002, 0.004
Pre-valence	-0.006	0.000	<.001	-0.006, -0.005
Pleasure Group * Time	-0.076	0.009	<.001	-0.093, -0.058
Sexual Arousal Group * Time	-0.057	0.009	<.001	-0.075, -0.040
Vulnerable Narcissism * Time	-0.008	0.000	<.001	-0.001, -0.001
Vulnerable Narcissism * Pleasure Group * Time	0.001	0.000	<.001	0.000, 0.001
Vulnerable Narcissism * Sexual Arousal Group * Time	0.004	0.000	<.001	-0.003, -0.002
Blinks	-0.001	0.000	<.001	-0.001, -0.001
Time * Blinks	0.002	0.000	<.001	0.002, 0.001
Pleasure Group * Time * Blinks	-0.002	0.000	<.001	0.000, 0.001
Sexual Arousal Group * Blinks	0.001	0.000	<.001	0.001, 0.001
Sexual Arousal Group * Time * Blinks	-0.003	0.000	<.001	-0.002, -0.001
Nonsignificant				
Pleasure Group	0.033	0.075	.660	-0.116, 0.182
Sexual Arousal Group	0.028	0.073	.704	-0.118, 0.173
Vulnerable Narcissism	0.000	0.000	.808	-0.001, 0.001

Vulnerable Narcissism * Pleasure Group	-0.000	0.001	.902	-0.001, 0.001
Vulnerable Narcissism * Sexual Arousal Group	-0.000	0.001	.817	-0.001, 0.001
Pleasure Group * Blinks	-0.000	0.000	.193	-0.000, 0.000
Outcome Binding Model				
Intercept	0.053	0.113	.639	-0.172, 0.278
Time	-0.055	0.008	<.001	-0.071, -0.039
Pre-arousal	-0.002	0.000	<.01	-0.003, -0.001
Pleasure Group * Time	0.107	0.011	<.001	0.086, 0.129
Sexual Arousal Group * Time	0.087	0.011	<.001	0.066, 0.109
Vulnerable Narcissism * Time	0.000	0.000	<.001	0.000, 0.001
Vulnerable Narcissism * Pleasure Group * Time	-0.001	0.000	<.001	-0.001, -0.001
Vulnerable Narcissism * Sexual Arousal Group * Time	-0.001	0.000	<.001	-0.001, -0.000
Blinks	-0.000	0.000	<.05	-0.000, -0.000
Time * Blinks	0.001	0.000	<.001	0.000, 0.001
Pleasure Group * Time * Blinks	0.001	0.000	<.01	0.000, 0.001
Sexual Arousal Group * Blinks	0.001	0.000	<.001	0.000, 0.001
Sexual Arousal Group * Time * Blinks	-0.002	0.000	<.001	-0.002, -0.001
Nonsignificant				
Pleasure Group	0.124	0.152	.418	-0.178, 0.425
Sexual Arousal Group	0.149	0.148	.319	-0.146, 0.443
Vulnerable Narcissism	0.000	0.001	.650	-0.001, 0.002
Vulnerable Narcissism * Pleasure Group	-0.001	0.001	.648	-0.003, 0.002

Vulnerable Narcissism * Sexual Arousal Group	-0.001	0.001	.294	-0.003, 0.001
Pleasure Group * Blinks	0.000	0.000	.461	-0.000, 0.000

6.3.2.2.4 Interaction of Emotion Induction, Time and Trait Anxiety on Binding

Including trait anxiety in the analysis, the decrease in binding after the sexual arousal induction compared to the neutral induction disappeared. The pleasure induction however, had significant effects on action and outcome binding compared to the neutral emotion induction (interaction pleasure group * time). Pre-valence and pre-arousal influenced action binding, and only pre-arousal affected outcome binding. Both models rejected a hypothesised main effect of trait anxiety on action or outcome binding. The interaction of time * trait anxiety showed a reduction in action binding from pre- to post-measurement and an increase over time in outcome binding in individuals with higher trait anxiety (figure 8).

With regards to blinks indicating dopaminergic activity, a main effect of blinks and significant interactions for time * blinks, pleasure group * time * blinks, sexual arousal group * blinks, sexual arousal group * time * blinks were revealed for action binding. For outcome binding no main effects of blinks and no interactions of pleasure group * blinks and pleasure group * blinks * time were observed emphasizing that dopaminergic activity can be observed more consistently in action binding than outcome binding (table 22).

Figure 11

Change in action and outcome binding between pre- and post-induction task by group (difference score, post-pre) for trait anxiety. Above 0 = increase in binding from pre- to post-measurement, below 0 = decrease in binding from pre- to post-measurement.

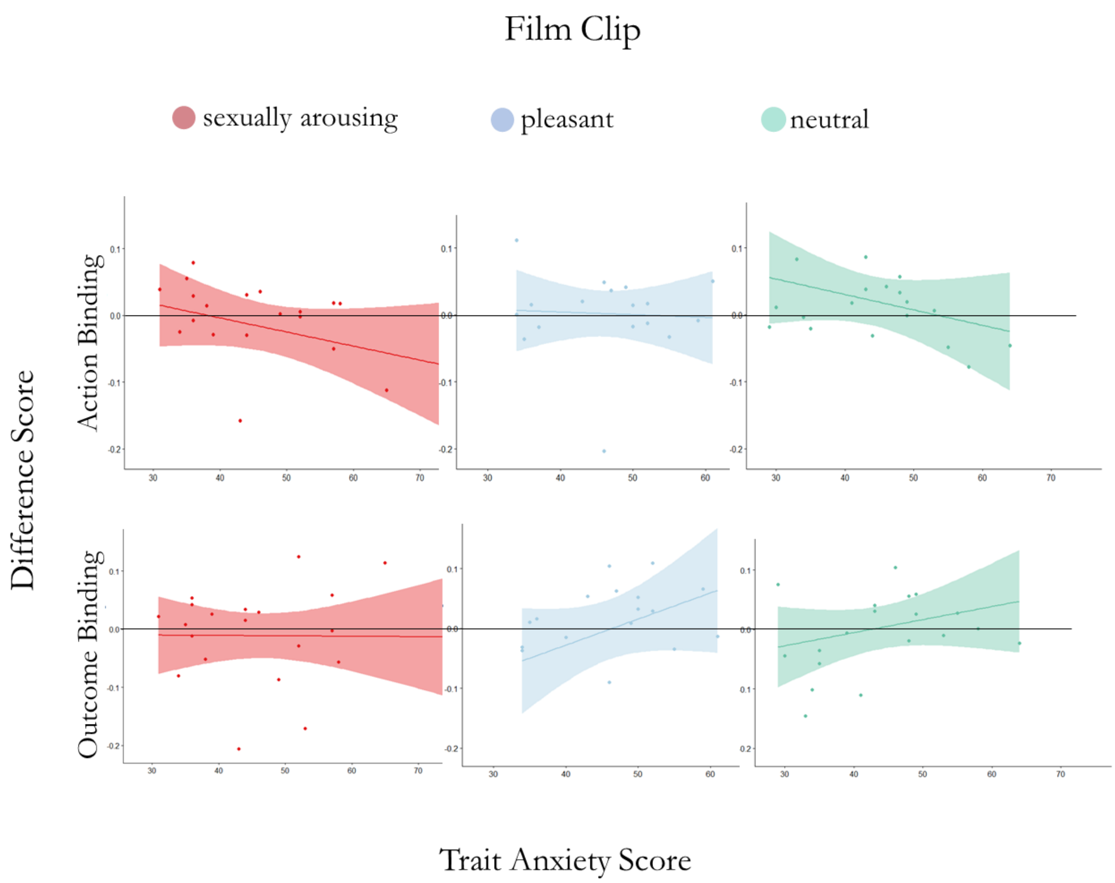


Figure 11 shows a decrease in action binding after the emotion induction for the sexually arousing and emotionally neutral film clips with higher trait anxiety; action binding was not impaired in participants with lower anxiety after the sexual arousal induction. The pleasure induction did not evoke differences in action binding independent of anxiety scores. In outcome binding, the neutral and the pleasure induction induced an increase in participants with higher trait anxiety and a decrease in participants with lower anxiety, whereas the sexual arousal induction impaired outcome binding slightly in regardless of anxiety scores.

Table 22

Linear mixed models for action binding and outcome binding.

*Fixed effects: Time * group * trait anxiety, pre-valence, pre-arousal, blinks * time * group and participants as random intercept (N = 59, number of observations = 11676).*

Variable	Estimate	*SE*	*p*	*95% CI*
Action Binding Model				
Intercept	0.019	0.046	.684	-0.072, 0.110
Time	0.122	0.005	<.001	0.111, 0.1318
Pre-arousal	0.003	0.000	<.001	0.002, 0.004
Pre-valence	-0.007	0.000	<.001	-0.008, -0.007
Pleasure Group * Time	-0.070	0.008	<.001	-0.087, -0.054
Trait Anxiety * Time	-0.003	0.000	<.001	-0.003, -0.003
Trait Anxiety * Pleasure Group * Time	0.001	0.000	<.001	0.001, 0.002
Blinks	-0.000	0.000	<.001	-0.001, -0.000
Time * Blinks	0.002	0.000	<.001	0.002, 0.002
Pleasure Group * Time * Blinks	-0.001	0.000	<.001	-0.002, -0.001
Sexual Arousal Group * Blinks	0.001	0.000	<.001	0.001, 0.001
Sexual Arousal Group * Time * Blinks	-0.003	0.000	<.001	-0.003, -0.003
Nonsignificant				
Pleasure Group	0.047	0.072	.520	-0.097, 0.191
Sexual Arousal Group	-0.036	0.060	.550	-0.157, 0.084
Sexual Arousal Group * Time	-0.013	0.007	.083	-0.027, 0.002
Trait Anxiety	0.001	0.001	.553	-0.001, 0.003
Trait Anxiety * Pleasure Group	0.001	0.002	.732	-0.004, 0.003

Trait Anxiety * Sexual Arousal Group	0.001	0.001	.475	-0.002, 0.004
Trait Anxiety * Sexual Arousal Group * Time	0.000	0.000	.067	-0.000, 0.001
Pleasure Group * Blinks	-0.000	0.000	.169	-0.000, 0.000
Outcome Binding Model				
Intercept	0.040	0.087	.647	-0.134, 0.214
Time	-0.106	0.006	<.001	-0.118, -0.094
Pre-arousal	-0.006	0.000	<.001	-0.007, -0.005
Pleasure Group * Time	-0.114	0.010	<.001	-0.133, -0.094
Sexual Arousal Group * Time	0.145	0.009	<.001	0.127, 0.162
Trait Anxiety * Time	0.002	0.000	<.001	0.002, 0.003
Trait Anxiety * Pleasure Group * Time	0.002	0.000	<.001	0.002, 0.003
Trait Anxiety * Sexual Arousal Group * Time	-0.003	0.000	<.001	-0.003, -0.002
Time * Blinks	0.000	0.000	<.001	0.000, 0.001
Pleasure Group * Time * Blinks	0.000	0.000	<.05	0.000, 0.001
Sexual Arousal Group * Blinks	0.001	0.000	<.001	0.000, 0.001
Sexual Arousal Group * Time * Blinks	-0.001	0.000	<.001	-0.002, -0.001
Nonsignificant				
Time				
Pleasure Group	0.134	0.139	.338	-0.142, 0.410
Sexual Arousal Group	-0.062	0.116	.594	-0.292, 0.168
Trait Anxiety	0.002	0.002	.335	-0.002, 0.006
Trait Anxiety * Pleasure Group	-0.002	0.003	.551	-0.008, 0.004

Trait Anxiety * Sexual Arousal Group	0.001	0.003	.687	-0.004, 0.006
Blinks	-0.000	0.000	.323	-0.000, 0.000
Pleasure Group * Blinks	0.000	0.000	.377	-0.000, 0.000

6.3.2.2.5 Interaction of Emotion Induction, Time and Psychopathy on Binding

Linear mixed models taking the interaction of emotional states * psychopathy into account, confirmed the effects of the sexual arousal induction on action binding (sexual arousal group * time) and revealed stronger effects of the pleasure induction (pleasure group * time) on outcome binding. However, the model did not reveal the predicted main effect of psychopathy on action nor outcome binding. We found an interaction of time * psychopathy for outcome binding showing a decrease in post-binding in individuals with higher psychopathy; no such effects were observed for action binding. However, we found significant effects in both binding components for psychopathy * sexual arousal group * time as well as psychopathy * pleasure group * time. Pre-arousal was not significant for outcome binding when psychopathy is considered, and effects of blinks hence dopaminergic activity were more pronounced for action binding than for outcome binding (table 23).

Figure 12

Change in action and outcome binding between pre- and post-induction task by group (difference score, post-pre) for psychopathy. Above 0 = increase in binding from pre- to post-measurement, below 0 = decrease in binding from pre- to post-measurement.

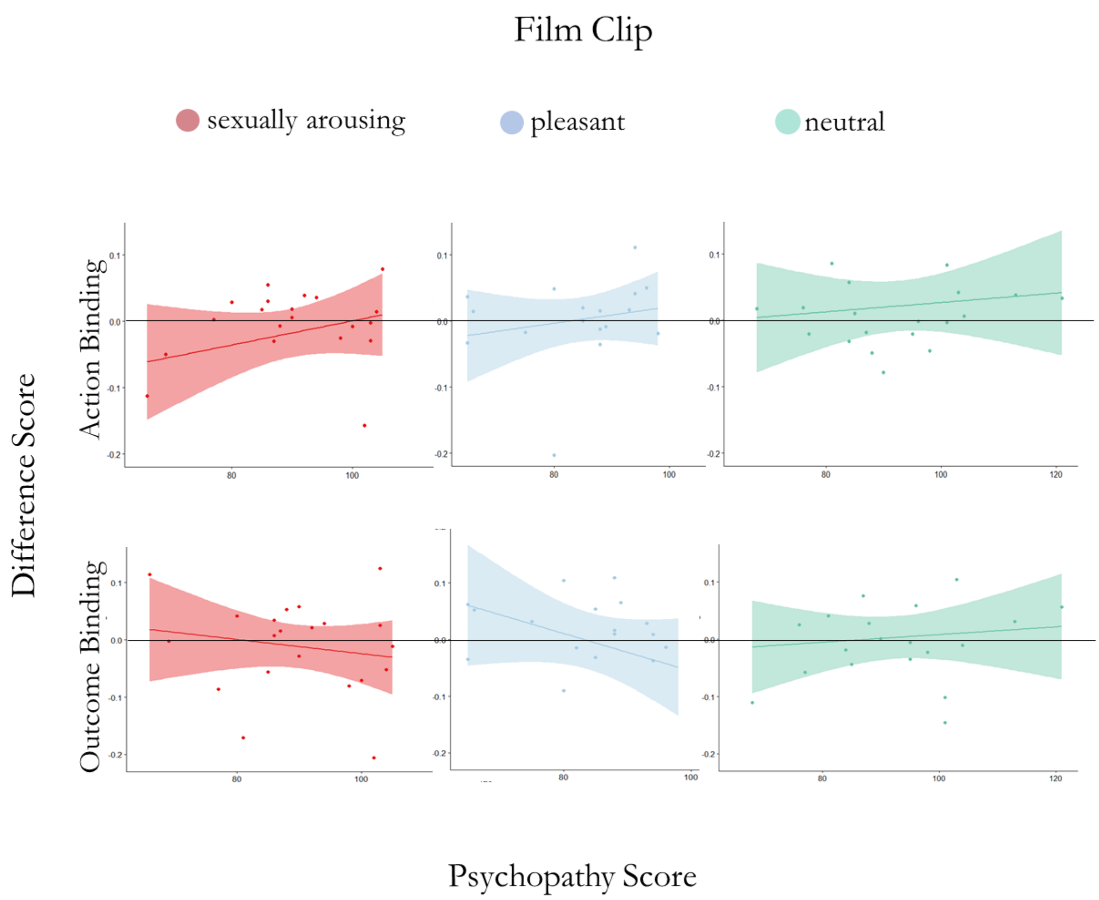


Figure 12 shows increases in action binding after all emotion inductions with higher psychopathy scores and a decrease after the sexually arousing and pleasant film clips in participants with lower psychopathy scores; the emotionally neutral film clip did not induce changes in participants lower on psychopathy. Outcome binding showed reversed patterns for psychopathy scores. Higher psychopathy scores were associated with a decrease after watching the sexually arousing film clip, a decrease after the pleasant film clip and an increase after the emotionally neutral film clip. Lower psychopathy scores were linked to an increase in outcome binding in pleasure and sexual arousal and a decrease after watching the emotionally neutral film clip.

Table 23

Linear mixed models for action binding and outcome binding.

*Fixed Effects: Time * group * psychopathy, pre-valence, pre-arousal, blinks * time * group and participants as random intercept (N = 59, number of observations = 11676).*

Variable	Estimate	*SE*	*p*	*95% CI*
Action Binding Model				
Intercept	0.060	0.069	.390	-0.078, 1.981
Time	-0.032	0.009	<.001	-0.050, -0.015
Pre-arousal	0.001	0.000	<.01	0.000, 0.002
Pre-valence	-0.005	0.000	<.001	-0.006, -0.004
Pleasure Group * Time	-0.086	0.014	<.001	-0.114, -0.058
Sexual Arousal Group * Time	-0.133	0.012	<.001	-0.157, -0.109
Psychopathy * Pleasure Group * Time	0.001	0.000	<.001	0.001, 0.001
Psychopathy * Sexual Arousal Group * Time	0.001	0.000	<.001	0.001, 0.002
Blinks	-0.000	0.000	<.001	-0.000, -0.000
Time * Blinks	0.002	0.000	<.001	0.002, 0.002
Pleasure Group * Time * Blinks	-0.002	0.000	<.001	-0.002, -0.001
Sexual Arousal Group * Blinks	0.001	0.000	<.001	0.001, 0.001
Sexual Arousal Group * Time * Blinks	-0.002	0.000	<.001	-0.003, -0.002
Nonsignificant				
Pleasure Group	0.020	0.107	.853	-0.194,0.234

Sexual Arousal Group	0.164	0.103	.115	-0.040, 0.368
Psychopathy	-0.000	0.001	.753	-0.002, 0.001
Psychopathy * Time	0.000	0.000	.064	0.000, 0.001
Psychopathy * Pleasure Group	0.000	0.001	.980	-0.002, 0.002
Psychopathy * Sexual Arousal Group	0.001	0.001	.135	-0.004, 0.001
Pleasure Group * Blinks	0.000	0.000	.116	-0.001,0.000
Outcome Binding Model				
Intercept	0.174	0.141	.222	-0.107, 0.454
Time	-0.068	0.009	<.001	-0.088, -0.049
Pleasure Group * Time	0.354	0.016	<.001	0.324, 0.385
Sexual Arousal Group * Time	0.165	0.014	<.001	0.137, 0.193
Psychopathy * Time	0.001	0.000	<.001	0.000, 0.001
Psychopathy * Pleasure Group * Time	-0.004	0.000	<.001	-0.005, -0.004
Psychopathy * Sexual Arousal Group * Time	-0.002	0.000	<.001	-0.002, -0.001
Blinks	-0.000	0.000	<.05	-0.001, -0.000
Time * Blinks	0.000	0.000	<.001	0.001, 0.001
Pleasure Group * Time * Blinks	-0.001	0.000	<.05	0.000, 0.001
Sexual Arousal Group * Blinks	0.001	0.000	<.001	0.001, 0.001
Sexual Arousal Group * Time * Blinks	0.001	0.000	<.001	-0.002, -0.001
Nonsignificant				
Pre-arousal	0.000	0.000	.495	-0.001, 0.001

Pleasure Group	0.067	0.218	.759	-0.368, 0.502
Sexual Arousal Group	-0.274	0.208	.193	-0.689, 0.141
Psychopathy	-0.001	0.151	.586	-0.004, 0.002
Psychopathy * Pleasure Group	-0.000	0.002	.929	-0.005, 0.005
Psychopathy * Sexual Arousal Group	0.003	0.002	.204	-0.002, 0.007
Pleasure Group * Blinks	0.000	0.000	.853	-0.000, 0.000

6.4 Discussion

In this third experiment, we addressed the gap in the sense of agency research between emotional states and personality traits by investigating their interactive influence on the binding components. Therefore, high arousing and low arousing positive states associated with dopamine release, specifically sexual arousal and calm pleasure, were induced. We indexed dopamine release via spontaneous eye blink rates, physical arousal by pupil dilation, skin conductance and heart rate and subjective emotional response by self-report of affective valence and arousal. We expected and confirmed reduced action binding in sexual arousal and hypothesised a facilitation effect of calm pleasure on action binding; which the data did not support. Results for outcome binding were less pronounced but still significant which was not hypothesised. Independent of emotional manipulation, higher vulnerable narcissism and more substance use history were expected to show decreased binding which was partially supported by an interaction of time and vulnerable narcissism. The interaction of substance use history and time indicated increased binding for both components. Lower trait anxiety and higher psychopathy were expected to show increased binding. Interaction of psychopathy and time suggested intact action binding but reduced outcome binding in higher psychopathy, interaction of trait anxiety and time showed the reversed pattern: reduced action binding, increased outcome binding. Personality traits did moderate emotional states, however, no main effects for personality traits nor for substance use history were found for binding. Blink data suggest that action binding is more closely connected to the dopaminergic system than outcome binding, in line with the hypothesis.

6.4.1 Placement of Results in Current State of Research

6.4.1.1 Emotional States

We found impaired action binding in sexual arousal as predicted, increased action binding after the neutral emotion induction and no change in action binding after the pleasure induction, which was unexpected. The decrease in outcome binding after the sexual arousal induction was also significant but less pronounced than in action binding. Pre-affective ratings showed a main effect of pre-valence on action binding and of pre-arousal on outcome binding, higher scores linked to reduced binding, independent of emotion induction. Our results are in line with previously reported effects for the negative arousing states fear and anger for action binding (Christensen et al., 2019) and extended effects for outcome binding. Effects for unspecific general arousal showed an increase in intentional binding measured with the interval estimation task in previous research (Wen et al., 2015). However, it has to be considered that general arousal and sexual arousal might differ to some extent as sexual arousal has been shown to overlap with negative emotions (e.g. Peterson & Janssen, 2007), thus it acts as an inhibitor of cognitive processes (e.g. Most et al., 2007).

6.4.1.2 Personality Traits and Substance Use History

The previously found effects for personality traits on binding (Asai & Tanno, 2008; Hascalovitz & Obhi, 2015) could not be enlarged by main effects for narcissism, psychopathy and trait anxiety, nor for substance use history. However, all investigated individual characteristics did interact with time. In terms of more reported substance use history, increased action and outcome binding post-emotion induction were observed. Findings for substance use history and intentional binding in this study are in contrast to results of related research fields such as that substance use has been associated with low self-control and impairments in cognitive control (Flexon et al., 2016; Volkow et al., 2013).

Although this third study indicated that narcissism interacts with time rather than having a main effect on binding, the direction of results seems to be in line with our predictions: there was a reduction in binding over time after all emotional manipulations. Dimaggio and Lysaker (2015) already predicted that vulnerable narcissism could be linked to reduced agency as these individuals often experience symptoms of depression or low self-esteem and thus experience diminished agency (Zeigler-Hill et al., 2011).

Results for trait anxiety showed a reduction in action binding and an increase in outcome binding after the emotion manipulation. Other forms of anxiety have been claimed to suffer from disruptions in sense of agency caused by mistrust in their own actions (Gallagher & Trigg, 2016). This feeling of uncertainty about, and lack of control over their own action performance could enhance the awareness of the consequences. Thus, the action outcomes build up to a future threat which could explain the increased outcome binding. This would be in line with previous research showing that higher trait anxiety has lower levels of reported perceived control, especially for unpredictable, aversive events as they induce uncertainty about the occurrence of future threat (Alvarez et al., 2015).

Intact action binding and reduced outcome binding for higher psychopathy after all emotion manipulations fits with previous research reporting adequate interpretation of actions but a bias in the interpretation of the consequences' impact on others (Brazil et al., 2011). The interactions of time and personality support the view, that individual characteristics determine the extent of control we have over our actions and consequences—at least over time. However, as no main effects were found, it should be considered that the differences in personality traits and time might interact with the responses to emotional states rather than showing individual differences independent of emotional reactivity.

6.4.1.3 Emotional States and Personality

In terms of interactive effects of emotional states and individual characteristics, increased action and outcome binding when sexually aroused, and increased outcome binding in pleasure for individuals who reported more substance use (lifetime) could be observed. An explanation for these increases might potentially be found in the link of substance use history, impulsivity and sensation seeking traits (Holmes et al., 2016): Sensation seeking (also novelty or arousal seeking) describes the tendency to seek varied, novel, complex, and intense sensations and experiences combined with the inclination to take risks for the sake of such experiences (Zuckerman, 2010). As such, these tendencies could trigger different responses to the emotional states causing the increase in binding after watching the film clips.

Higher vulnerable narcissism showed reduced action and outcome binding in sexual arousal and reduced outcome binding in pleasure. Reduced outcome binding in a positive state indicates that the precondition of a rejection harming the self-esteem as proposed by Dimaggio and Lysaker (2015) does not even need to be met. The valence of emotional content seems to be irrelevant for the feeling of agency in narcissism, as it was reduced either way.

In higher psychopathy, the feeling of control over actions was intact or even increased while the awareness of the consequences was reduced—the consequences were disconnected from the actions—when sexually aroused. Differences in motivational processing and attention in psychopathy, such as that individuals scoring higher on psychopathy have increased task focus and are less impacted by stress-inducing situations than individuals with moderate to lower scores (Baskin-Sommers et al., 2012; O'Leary et al., 2010), could explain the intact feeling of control over actions.

Similarly, the feeling of control over actions seemed be more affected in higher trait anxiety than in lower trait anxiety. Previous research has indicated that pre-exposure to a short film eliciting anxiety produces increases in sexual arousal when viewing an erotic film compared with pre-exposure to a neutral film (Hoon et al., 1977; Wolchik et al., 1980). If higher trait anxiety is also linked to stronger responses of sexual arousal, like state anxiety is, this might explain why the feeling of control is reduced more. The awareness of consequences in the neutral and pleasant states was increased in higher trait anxiety, which could reflect an attentional bias found in previous research: individuals with higher trait anxiety have been reported to show facilitated engagement and impaired disengagement for emotional stimuli (Koster et al., 2006).

6.4.1.4 Indications in Physiology: Arousal and Dopamine

A strength of this study was the multilevel approach of assessing arousal in different modalities, on a cognitive and a physiological level. The physiological measure provided continuous data during the tasks for arousal, the arousal ratings are pointing more to a specific moment in time, before and after the task, revealing distinct effects on the binding components. From this, models can control for differences at baseline and during the task in different modalities between the participants, validating the emotion manipulation.

The results for blinks support the idea that action binding is more closely linked to the dopaminergic system than outcome binding (Tanaka et al., 2019) as effects of blinks were more pronounced and consistent for action binding. Nevertheless, outcome binding also seemed to be affected by dopamine activity, which was not postulated. The fact that blinks and their interactions with the emotional states changed effects such as time and pre-arousal in the models underlines their importance for binding.

6.4.2 Limitations

In terms of limitations, there are two main aspects that need to be addressed. First, our study was not able to replicate previously reported alterations in binding for grandiose narcissism (Hascalovitz & Obhi, 2015) as group differences were found prohibiting further analyses, nor did the study fully replicate the results of our first study for vulnerable narcissism and substance use history. As the sample for this third was rather small, we only used a lifetime score for substance use history in this study and did not split the substances into different types. Thus, a larger sample with more substance users is necessary to evaluate the interactive effects of substance use and emotional states. The restriction interpretability and generalisation due to sample size also applies to the interactive effects of personality traits and emotional states (see general discussion).

Second, group differences limited the interpretability of the pleasure induction for outcome binding, so that replication is needed to understand to what extend pleasure influences this component of the sense of agency. However, participants were randomly assigned to the groups and the pleasant film clip did cause an increase in subjective valence ratings, as such, this limitation does not seem to be caused by failures in the design.

6.4.3 Conclusion

In contrast to our second experiment, this study showed that sexual arousal impairs the feeling of control over actions. Our results also underline the importance of personality for the feeling of control in highly emotional states. For example, individuals scoring high on vulnerable narcissism seemed to be more vulnerable to show a reduced sense of agency in sexual arousal. Individuals with higher trait anxiety were also disrupted in their feeling of control over actions but showed an increased awareness of the consequences. In contrast, people scoring higher on psychopathy seemed to be more resilient to sexual arousal. At the same time, these individuals showed a reduction in the feeling of control over consequences which did not occur in other participants, indicating a moment of psychological distancing from the action outcome. The sense of agency appeared to be unaffected by sexual arousal in individuals who reported more substance use history. The results of this study suggest that individual characteristics might interact with emotional states causing different effects on the sense of agency. If this is the case, individual characteristics and circumstances should be considered more in sentencing and treatment.

7 General Discussion

7.1 Summary

This thesis attempts to get a step closer to operationalising the dopamine hypothesis in different non-invasive ways. In the first study, we focused on finding determinants in sense of agency in substance use history and personality traits (Render & Jansen, 2019). In the second study we induced sexual arousal and shifted the focus from overall intentional binding to the binding components—action and outcome binding (Render & Jansen, 2020). The third study combined the designs of the first two studies investigating the interactive effects of personality variables and emotional states. Physical arousal was assessed with pupil dilation, skin conductance and heart rate; dopaminergic activity was indexed with spontaneous eye blink rates (Render et al., under review).

Results of the first study showed that binding is reduced in higher vulnerable narcissism and more reported substance use history in line with the hypotheses. No effects were found for grandiose narcissism (Render & Jansen, 2019). In the second study we induced sexual arousal predicting a reduction in action binding and no effects in outcome binding. Instead, we observed the predicted effects for unspecific general arousal (Render & Jansen, 2020). Findings of the third experiment suggested that sexual arousal impairs action and outcome binding both, with stronger effects for action binding. Although main effects for personality traits on binding could not be found, personality did interact with time and emotional states: higher vulnerable narcissism was associated with reductions in both binding components after emotion inductions, higher trait anxiety showed reduced action binding but increased awareness of the action consequences and in higher psychopathy action binding was intact, outcome binding was reduced—a disconnection of the consequences from the actions. Unexpectedly, more reported substance use history was linked to increased action and outcome binding when sexually aroused (Render et al., under review).

7.2 Measuring Intentional Binding

Several methods have been introduced to measure intentional binding leading to different results. Wen et al. (2015) used the interval estimation task that measures the interval between action and consequence directly via reproducing the length of the interval or asking for numerical estimates of it. We used the Libet Clock task in all three studies, a task which captures the perception of event boundaries. Event boundaries are the separating elements between action and consequences, e. g. distinguishing the end point of the key press and the starting point of the tone. We can report good reliability scores for the Libet clock task (see third study, Render et al., under review) and in line with this, data from a meta-analysis has shown higher effect sizes for the Libet Clock task compared to the interval estimation task. It should be noted that the authors could not infer from the data whether the variance between the two tasks resulted from the differences in their underlying processes or merely from lower sensibility or reliability of the interval estimation task. However, they did question the validity of the interval estimation task to detect subtle sensomotoric changes in binding (Tanaka et al., 2019). This is in accordance with other researchers who suggested that the interval estimation task does not necessarily involve agency or intentionality (Dewey & Knoblich, 2014): Shifts in event boundaries could theoretically occur independent of changes in the representation of the temporal interval separating the two events (Humphreys & Buehner, 2010). As the interval reproduction task shows temporal binding at much longer intervals than the Libet clock task (Humphreys & Buehner, 2009, 2010), it remains possible that the feeling of self-agency modulates the perception of these event boundaries but does not modulate the perception of the temporal interval itself. It has therefore been outlined that results of the interval reproduction are determined by the perception of a causal relationship between two events but neglect underlying intentionality or agency (Dewey & Knoblich, 2014). This means, temporal binding in the interval estimation task might just reveal the causal relationship of two events independent of agency. The use of different methods to assess intentional binding might explain the discrepancy in results for arousal: in contrast to Wen et al. (2015) who found increased binding (interval estimation task), we found reduced binding in our second and third experiment (Libet Clock task) (Render et al., under review; Render & Jansen, 2020).

7.3 Emotional States: Arousal and Valence

All of the presented studies inducing emotional states during action performance reported high arousal, but valence varied across the studies: Wen et al. (2015) induced unspecific general arousal with neutral valence; Christensen et al. (2019) induced fear and anger states that both had negative valence. The valence of sexual arousal, induced in our studies (Render et al., under review; Render & Jansen, 2020) a bit more complex. Sexual arousal is rewarding (Oei et al., 2012), however, it also co-occurs with ambivalent affect (e.g. Peterson & Janssen, 2007). Moreover, effects in our second study were associated with changes in general unspecific arousal only, which is considered to have a neutral valence. Previous studies focusing on the valence of the consequences (instead of valence during action performance) came to the result that equally arousing emotional stimuli can have opposite effects on sense of agency depending on their valence: studies using financial incentives or emotional sounds as action outcomes, revealed that negative outcomes reduced intentional binding relative to neutral outcomes. Yet enhancing effects of positive outcomes on intentional binding were neglectable relative to neutral outcomes (Gentsch & Synofzik, 2014; Takahata et al., 2012; Yoshie & Haggard, 2013). In these studies, arousal cannot explain a valence-dependent effect since positive and negative stimuli were rated as equally arousing. Hence, in contrast to the consequence's valence (e.g. financial incentives or emotional sounds), variation in valence during action performance (e.g. emotional states) does not seem to change the effects on binding: Results for negative (fear and anger), neutral (general arousal, second study) and positive (sexual arousal, third study) valence in high arousal all showed reductions in binding. The fact that three arousing states varying in valence have all produced a reduction in the sense of agency suggests that non-specific factors that accompany our emotions, such as arousal in general, modulate the sense of agency rather than the particular emotion itself. The only study that reported increased binding in arousal by Wen et al. (2015) has used a task in which the validity has been questioned (Tanaka et al., 2019), and no arousal ratings of the actual participants performing the intentional binding task were provided, so that results are limited in their interpretability.

However, in terms of arousal intensity, it could also be argued that arousal levels in the study of Wen et al. (2015) could have been of low or medium intensity since they were induced by red jumping squares only. Thus, low or moderate arousal could explain a facilitation effect on binding, whereas reductions in binding observed in our studies and by Christensen et al. (2019) could be caused by high arousal. Related research fields have discussed the Yerkes-Dodson Law assuming an inverted u-shaped relationship between arousal and other cognitive tasks in this context (Peifer et al., 2014) with very high and very low arousal leading to suboptimal performance. This shape has also been brought up for the relationship of the sense of agency and arousal (Herman & Tsakiris, 2020). However, consistent evidence to confirm this theory either for agency or for other cognitive processes is still missing. Others have argued that the relationship is more complex than that (Hanoch & Vitouch, 2004).

In order to understand why the second study revealed effects of general arousal (Render & Jansen, 2020) and third of sexual arousal (Render et al., under review), the study designs need to be compared more closely. For self-reported affect, experiment two used the SAM and experiment three the affective grid, both scales ranging from 1 to 9. Analyses confirmed successful arousal manipulation with a significant increase in arousal after watching the sexual arousing film clip in both studies, although potentially more pronounced in the third experiment. However, valence ratings showed an increase in the third but not in the second experiment. Several reasons could be considered to explain this inconsistency: first, the selection of scenes from the sexually arousing film clip differed slightly between the studies. The film clip in the second study started with a short conversation which had been reported to be irritating by participants of the second study. Thus, this scene was excluded in the third study. Second, the two studies were conducted in different countries—Germany and New Zealand—so that cultural differences might have contributed to differences in reception. A review (Rowland & Uribe, 2020) investigating cross-cultural pattern based on Pornhub data showed that use of porn does vary between cultures. For example, use of porn was higher per capita and porn users were on average older in New Zealand compared to Western and Central Europe. Most relevant for our results was, that threesomes were ranked in the top three for types of pornography in New Zealand, whereas threesomes were a less popular porn category in Western and Central Europe (Rowland & Uribe, 2020). As our sexual arousing film clip showed a threesome, this could explain why the valence was rated higher in the third study conducted in New Zealand than in the second study conducted in Germany. Third, as physiological measures (pupil dilation, skin conductance and heart rate) were only collected in the third study, it cannot fully be ruled out that these measures have impacted the participants' reaction to the film clips.

In terms of low arousal, our attempt to operationalise pleasure to investigate the effect of valence is limited in interpretation at this point. While action binding was unchanged after the pleasure manipulation, rejecting the predicted facilitation effect, a main effect of the pleasure group in one of the outcome binding models was observed. Absolute values showed that outcome binding was already higher in the pleasure group than in the other groups in the first intentional binding measurement. In addition, subjective ratings did not confirm specific effects for the pleasure induction. Instead, increased valence ratings were observed in all three groups which limits the interpretability for the results of calm pleasure specifically.

Hence, the question whether arousal or valence determine the direction of effects on binding cannot fully be answered at this point. Including a state of high arousal and purely positive valence or a state of low arousal and negative valence, could potentially clarify, what role valence plays in high arousing states. However, since pre-affect was included in the analysis of the third study, we have preliminary evidence suggesting that outcome binding is more affected by arousal than valence, whereas action binding is influenced by both affect dimensions, valence and arousal. Why only action binding is affected by valence needs further investigation before concrete assumptions about reasons can be made. However, action binding does seem to be more vulnerable to environmental changes than outcome binding.

By including both components in the analyses leading to different results, we were able to present evidence that action and outcome binding are likely to be driven by different underlying processes (Tanaka et al., 2019). Hence, our design offers an insight into the direct effects of an emotional state during action performance on action binding and outcome binding separately for the first time. While many studies have focused on manipulating the action outcome to investigate how much each component is affected by it, no study has investigated action and outcome binding in the effects of emotional states during action performance before. The awareness of consequences measured with outcome binding, although, is equally important for legal and social responsibility than feeling of control over action (action binding).

7.4 Personality and Substance Use History

Another relevant factor for criminal behaviour is a history of substance use (Flexon et al., 2016). Previous research has reported increased intentional binding in ketamine administration (Moore et al., 2011; Moore et al., 2013) and a binding boost in the Parkinson medication L-Dopa (Moore et al., 2010). In our first study (Render & Jansen, 2019), we investigated whether alterations in binding are also linked to substance use history beyond cannabis, particularly to the substances cannabis, ecstasy, and cocaine. Results showed reduced intentional binding compared to controls without substance use history, which could indicate a lower accessibility of dopamine decreasing binding. Results of our third study (Render et al., under review) in contrast, do not confirm such a main effect of substance use history (as a sum score for lifetime, not split into subtypes) on binding, although an interaction of time and substance use history was observed. Interestingly, both binding components were increased after watching either of the three film clips. As participants in this study reported rather little substance use history, it remains possible that an occasional, more limited consume has different effects on agency than more frequent consume or early consume onset (Urban et al., 2012). Potentially levels of dopamine are not as affected as by higher consume.

Another potential explanation could be found in sensation seeking personality traits that have been reported to correlate with substance use (Holmes et al., 2016), however, these results are contrary to previous research of related fields (Volkow et al., 2013). When comparing the results of the two studies, results of our third study seem to be in contrast to what we found in first study and to results of related research fields, e.g. substance use has been associated with low self-control and impairments in cognitive control (Flexon et al., 2016; Volkow et al., 2013). It should be considered that the sample size of 60 participants in the third study limited the examination of single substances, thus we decided to define substance use as a continuous variable throughout lifetime for analyses. In contrast to that, our first study consisted of 210 participants so that we were able to divide the substances into different categories for analyses. This might have contributed to the differences between the two studies.

In terms of personality traits in general, no main effects on binding were found consistently across both studies (Render et al., under review; Render & Jansen, 2019). Higher vulnerable narcissism was associated with reduced binding in the first study (Render & Jansen, 2019), but this main effect was not replicated in the third study (Render et al., under review). However, as with substance use history, vulnerable narcissism did interact with time in the third study: binding was reduced after all three emotion inductions in higher vulnerable narcissism (Render et al., under review). Reduced agency in vulnerable narcissism has been predicted by other researchers (Dimaggio & Lysaker, 2015) as these individuals often experience symptoms of depression or low self-esteem and thus diminished agency (Zeigler-Hill et al., 2011). This rational is also found in the 'Perceived Control Theory of Narcissism' (Hansen-Brown, 2018): vulnerable narcissists have the feeling that the world is happening to them instead of them identifying as causal agents. They perceive low control over their own outcomes, the behaviour of others, and the world around them which makes them ambitious to protect themselves from negative outcomes. By doing so, they neglect pursuing positive outcomes showing a lack of intentionality. Grandiose narcissists whereas, perceive high control over these domains. This narcissist subtype pursues their desires, craves for influence over others by exploiting them for personal gain and maintaining power in relationships (Hansen-Brown, 2018). While a previous study has confirmed this theory with increased binding in grandiose narcissism (Hascalovitz & Obhi, 2015), we were not able to replicate these results: analyses of our first study rejected such effects (Render & Jansen, 2019), and analyses of our third study could not be performed because group differences limited the comparability of the three conditions (Render et al., under review). It remains unclear whether the lack of effects was sample related, e.g. low scores of grandiose narcissism in the first sample, method-dependent, e.g. because of different questionnaires that were used, or due to independence of the two constructs.

Effects of trait anxiety and psychopathy were examined in the third study (Render et al., under review). The interaction of trait anxiety and time indicated reversed patterns for the binding components: for higher trait anxiety action binding was reduced; outcome binding was increased after all film clips. The disruption of the feeling of control over actions (action binding) could be due to mistrust in the own actions (Gallagher & Trigg, 2016). Anxiety is moreover assumed to involve a tendency to focus on the uncertainty of the future outcomes (Floyd et al., 2005) which could explain the increase in outcome binding. Effects for higher psychopathy on the other hand, indicated that action binding remained intact in all emotional states, but outcome binding was reduced. Other agency studies resonate with our results, finding adequate interpretation of actions but a bias in the interpretation of the consequences' impact on others (Brazil et al., 2011).

To sum up, we have not consistently found main effects of the investigated personality traits on binding in our studies (Render et al., under review; Render & Jansen, 2019). Our findings suggest that these personality traits interact with time and emotional states, affecting the feeling of control in different ways (Render et al., under review). However, it should be considered that personality traits were measured via self-report, thus reflecting certain parts of the personality constructs only, which could have affected the results. The interactions of emotional states with personality traits and substance use history propose that reductions and increases in sense of agency could be function of emotion regulation strategies differing interindividually.

7.5 Substance Use History, Personality and Emotional States

The extent to which agency was impacted by sexual arousal appears to be dependent on individual characteristics in such a way as to form three patterns: fully disrupted (higher vulnerable narcissism and higher trait anxiety), partially disrupted (lower trait anxiety and higher psychopathy) and not affected at all (more reported substance use history) (Render et al., under review).

Higher vulnerable narcissism and higher trait anxiety were associated with reduced feeling of control over actions and consequences when sexually aroused in our third study (Render et al., under review). In narcissism, the lack of control in aroused state might result from maladaptive emotion regulation strategies that have been found in vulnerable narcissism, such as nonacceptance of one's own emotional responses, impulse control difficulties, limited access to emotion regulation strategies, and a lack of emotional clarity (Zhang et al., 2015). This way, vulnerable narcissists are experiencing negative affect and anxiety (Tracy et al., 2011) emphasising the overlap with trait anxiety. For higher trait anxiety, previous research supports the idea of lower levels of reported perceived control, especially for unpredictable, aversive events because these induce uncertainty about the occurrence of future threat. Hence, perceived control mediates the relationship between high-trait anxiety and exaggerated neural processing of emotionally significant events (Alvarez et al., 2015). When manipulating the level of perceived control over arousal, rather than examining perceived control as an outcome, higher anxiety sensitivity showed greater emotional responding in low control over arousal (Telch et al., 1996).

Individuals with lower trait anxiety, higher psychopathy and more reported substance use history seem to be less vulnerable to the sexual arousal induction. More reported substance use history was linked to an increased feeling of control over actions *and* consequences in sexual arousal (Render et al., under review). This result was unexpected because previous findings indicated the opposite, low self-control (Flexon et al., 2016) and dysfunctional emotion regulation and arousal reactivity (Kober, 2014; Poon et al., 2016). Substance use is found more often in certain personality traits such as sensation seeking (Holmes et al., 2016). Thus, it cannot be ruled out, that underlying personality traits have moderated the effects of substance use history and emotional states on binding. In terms of higher psychopathy and lower trait anxiety, our results suggest that higher psychopathy has an intact feeling of control over actions but a reduction in the feeling of control over consequences (Render et al., under review). Research has shown that psychopathic traits such as higher impulsivity are linked to greater reactivity to stimulation initially, but, arousal response also declines faster in sustained exposure, measured on a physiological level (Mathias & Stanford, 2003). A fast decline or habituation effect in sexual arousal could explain why the feeling of control over actions is not disrupted in higher psychopathy. In compliance with that, other findings suggest that psychopathy traits can contribute to rational decision making in socially difficult situations (Osumi & Ohira, 2010). At the same time, the link of actions and action outcomes seems to be disrupted which implies that a feeling of responsibility for action outcomes might not be present.

A partially functional sense of agency in higher psychopathy and lower trait anxiety does have implications for legal culpability. Previous research has postulated that psychopathy has alterations in agency that do not compare to normally functioning individuals (Fox et al., 2013). We specified this assumption showing that a disconnection of actions and consequences occurs in higher psychopathy (Render et al., under review). However, this does not imply that psychopathy is devoid of all agency in terms of how adult human agency is defined by law. While limitations in moral understanding, emotional processing and agency make it difficult to justify full responsibility and punishment, harmful acts should not happen without restraint, even if individuals with psychopathy are found to be not or only partially criminally responsible (Fox et al., 2013). Instead of seeking a purely punitive solution such as a prison sentence, it should be considered whether treatment options might improve the awareness of harmful consequences as our results indicate that this process is diminished in psychopathy.

The fact that the extent to which the feeling of control is affected by emotional states is determined by personality traits highlights that the individual characteristics need to be taken into account when evaluating levels of responsibility. Why these inter- and intraindividual difference in sense of agency occur, is not yet fully understood. Potentially, these differences could also be driven by alterations in the dopaminergic system.

7.6 Dopamine Hypothesis

Previous researchers have already highlighted dopamine as a determinant of intentional binding (Aarts et al., 2012; Graham et al., 2015; Moore et al., 2010), some have suggested that dopamine particularly determines action binding (Moore et al., 2010; Saito et al., 2015). Administration of testosterone (van der Westhuizen et al., 2017) for example increased action binding but not outcome binding in women and the authors suggested that this stemmed from a dopamine release caused by the testosterone induction. As strong motor predictions themselves can lead to binding, the authors speculated whether testosterone and/or dopamine change the perceived predictability of actions as an overly strong trust in the reliability of the own predictions via a positive mood (van der Westhuizen et al., 2017). Arousing states are associated with alterations in the dopaminergic pathways within different brain areas (Damsma et al., 1992; Giuliano & Allard, 2001), therefore, alterations in binding during arousal reflect the changes in the dopaminergic system involved in action execution (Tanaka et al., 2019). Reduced action binding, which was observed in both studies (two and three) (Render et al., under review; Render & Jansen, 2020), could result from a specific impairment in action planning or generating action outcome predictions (inaccurate predictions). In line with that view, we observed that results for blink rates, as an indicator for dopaminergic activity, and sexual arousal, a proxy for a high dopaminergic state, were more pronounced for action binding than for outcome binding (Render et al., under review). However, effects of sexual arousal and blink rates were also found for outcome binding in the third study, suggesting that outcome binding is not fully independent of the dopaminergic system. Of what shape the relationship between intentional binding and dopamine is, remains unclear at this stage. A linear link seems unlikely as binding was reduced in states that were used as a proxy for low (Render & Jansen, 2019) and high (Render et al., under review; Render & Jansen, 2020) dopaminergic activity. Another possibility could be an inverted u-function, which has been suggested for dopamine and other cognitive abilities such as cognitive control (Cools & D'Esposito, 2011), but potentially the relationship is more complex than that. Although we cannot define how dopamine and sense of agency interact precisely at this point, we have provided evidence that dopamine is more important for action binding and that the relationship between dopamine and sense of agency cannot be linear. However, the partial support for the dopamine hypothesis provided by this work could also be considered a limitation.

7.7 Limitations

In terms of other limitations, the first aspect that needs to be noted is that the increase of binding after the emotionally neutral film clip in the second (Render & Jansen, 2020) and the third experiment (Render et al., under review) is not yet fully understood. As two different film clips were used (the second of which was also pre-tested in an online survey to ensure neutrality), it seems unlikely that the film clips themselves were perceived better or worse. Another possibility is a learning effect, e.g. binding would have been higher without the neutral film clip exposure as well, as it results from experience gained in the first task. Comparing the groups with different emotionally neutral treatments, such as just taking a break without watching a film clip, might help to clarify this effect. However, it remains difficult to evaluate what exactly caused this effect since, to the best of our knowledge, no studies have reported long-term retest-reliability (days, weeks or months) of the intentional binding measures yet. Cronbach's alpha values in the third experiment, however, did indicate good internal consistency of our task (Render et al., under review).

A second point of critique are the limited sample sizes (first study N=210 (Render & Jansen, 2019), second study N = 90 (Render & Jansen, 2020), third study N = 60 (Render et al., under review)) that the results are based on currently, restricting the interpretability and generalisability. To evaluate whether effects remain and how strong the effects are, the studies need to be replicated with more participants. As the participants have mostly been students, it would be elucidating to run this experiment in an offender sample to see if results change when studying participants that have higher scores of psychopathy for example. Particularly offender populations are considered as highly psychopathy populations: whilst the prevalence of psychopathy in the general population is relatively low (0.3–2%), it is much higher among general offender populations (15-25%) (Lilienfeld & Arkowitz, 2007; Patrick & Drislane, 2015). Nonetheless, we were able to observe the alterations in binding even on a non-clinical level, which means that our results may apply to the general population as well.

This brings us to the third restriction, the transfer and application of the findings at this point in time. Our results cannot fully be generalised to sense of agency as a broader construct, as we only used one implicit method to measure intentional binding. However, as the validity of the interval estimation task has been questioned due to results of a meta-analysis (Tanaka et al., 2019), adding it as a second measure for intentional binding might not provide incremental validity. It could be interesting to see though, whether the effects we found can be replicated with another implicit method measuring the sense of agency. Besides intentional binding, a second implicit measure for sense of agency has been proposed: sensory attenuation. Sensory attenuation makes use of the fact that self-initiated action-effects are perceived less intense subjectively in direct comparison, e.g. a self-initiated tone is perceived less loud than a tone caused by others or machines (Sato, 2008; Weiss et al., 2011). However, the link between sensory attenuation and the sense of agency is still preliminary since the necessary preconditions are controversy (Dewey & Knoblich, 2014) and some results suggest a partial dissociation of sensory attenuation and the sense of agency (Weller et al., 2017). It seems to be that sensory attenuation relies on predictive mechanisms only (Horváth, 2015), whereas the sense of agency is determined by both, predictive and postdictive mechanisms (Haggard & Tsakiris, 2009; Tanaka et al., 2019). Future research could focus on finding equivalently valid measures to replicate our findings. In terms of explicit ratings, it has been well established that self-reported agency is another facet of agency, so that effects can be expected to differ.

7.8 Outlook for Future Research: Open Questions

As this work has set the focus on risk factors for criminal behaviour, emotional states enhancing the probability for underestimation of risks and engagement in reckless activities such as pleasure and sexual arousal (van Gelder, 2013) were considered as emotional states. However, in another context, more attention should be drawn to the emotional state sadness to investigate its influence during action performance on the feeling of control as it could have implications for depression for example. Sadness, with low arousal and negative valence, remains to complete the cluster for the two valence and arousal dimensions. Previous research indicates positive effects of sadness to some extent but not generally for all cognitive processes (Chepenik et al., 2007). Others claim broader benefits of negative affect for cognition, emotion, and interpersonal behaviour (Forgas, 2014).

The effects of emotional states on sense of agency could also be studied from a treatment perspective. It could for example be investigated whether psychological interventions, such as mindfulness, that have been shown to improve emotion regulation skills (e.g. Roemer et al., 2015), are able to reduce the impact of emotional states on sense of agency. Deficits in emotion regulation have among others been found in anxiety disorders (Mennin et al., 2009), psychopathy (Garofalo et al., 2018) and narcissism (Zhang et al., 2015).

Since differences in motivational processing and attention have been reported for different types of psychopathy (e.g. Sadeh & Verona, 2013), it might also be informative to differentiate components of psychopathy, namely coldheartedness, fearless dominance, and self-centred impulsivity. Specifically, recent research has suggested that individuals higher on the psychopathic trait fearless dominance are more reactive to positive stimuli, whereas those higher on self-centred impulsivity have a perceptual bias for negative stimuli (Yoon & Knight, 2015) which could impact the temporal binding in different ways. If the three subscales were to differ in terms of sense of agency, this would change the implications for legal culpability: psychopathy would matter less as a broader construct and could be replaced by research fields for the three subscales instead demonstrating the individual responses to emotional states more specifically.

Another great contribution to this stream of research would also be to focus more on underlying mechanisms causing interindividual differences. Subtle bodily cues for instance have received growing interest as they seem to affect our perception of the world, our actions and decisions (Herman & Tsakiris, 2020). According to previous findings, interoceptive processing regulates action generation, control, and self-attribution of action (A. C. Marshall et al., 2018) and the sense of agency is assumed to arise from the integration of interoceptive cues and exteroceptive sensory signals (Seth & Tsakiris, 2018). A recent study investigated the influence of interoceptive cues on the sense of agency with cardiac afferent signalling, the most commonly studied bodily cue, due to its regularity and frequency (Herman & Tsakiris, 2020). In this experiment, participants had a free choice between two stimuli presented on the screen. After a short delay, an outcome differing in valence (gain or loss), was presented auditorily either at the time of a heartbeat or in between two heartbeats. For the intentional binding measure, participants judged how much time had passed between their action and the outcome. Throughout, the action time (the time of the key press) was recorded with ECG to categorise, whether the action was made at a heartbeat or in between two heartbeats. Results showed that the sense of agency was higher for actions that were synchronous with heartbeats compared to actions between two heartbeats. This was unexpected as previous research had shown that events presented synchronous with heartbeat are perceived as more threatening and lead to inhibition of motor responses (Rae et al., 2018; D. R. Watson et al., 2019) because the heartbeats cause more pressure, thus physical arousal that can be perceived via sensors in the arteries (Herman & Tsakiris, 2020). Other researchers have suggested that the sense of agency is generated by a combination of internal motoric signals and external sensory (Moore et al., 2009). Future research could examine what type of cues—internal or external—is more important for the sense of agency and whether interindividual variance in the selection of cues are able to explain variations in the stability or flexibility of the sense of agency. A method to measure the reactivity to external stimuli is for instance sensory gating (e.g. Jones et al., 2016). In healthy individuals the phenomenon of sensory gating occurs when two stimuli are presented within a short interval as the reaction to second interval is significantly reduced measured via event-related potential. Thus, combining sensory gating and intentional binding could potentially reveal whether differences in the sensibility to external stimuli impacts the binding strength also.

Lastly, sense of agency research could switch its focus to a more (socially) interactive field. While the effect of personality characteristics and emotional states on sense of agency simulate a court scenario for the defendant's loss of control, the relation between one's own sense of agency and evaluating other's intentions is particularly important for the other side of the bench: the judge. In the current justice system, the judge sets the standard for the level of control they expect of the suspect. It would have crucial implications for current system if the judge's standards for feeling of control are actually determined by their sense of agency rather than if they were generated by external cues. Studies in this stream of research indicate an influence of social interaction on our own sense of agency (Ulloa et al., 2019) and on the evaluation of other's sense of agency (Reddish et al., 2020). In terms of an impact of social interaction on our own sense of agency, increased intentional binding in direct eye contact has been reported (Ulloa et al., 2019), potentially caused by enhanced self-processing. This effect occurred independent of the time of eye contact, either before action performance or as a result of the action. When we perform actions in social situations, eye contact acts as a cue intensifying our feeling of agency over actions and our feeling of responsibility over outcomes. The combined impact of emotional expressions and eye contact on the sense of agency could be a next step to a better understanding of how our sense of agency adjusts in social interaction (Ulloa et al., 2019). With regards to the influence of social interaction on the judgement of other people's agency, interesting results in terms of one's own and others actions relation have been shown: When being synchronous in a joint action task, participants judged their task-partner's sense of agency higher because the synchrony formed a sense of distributed agency (Reddish et al., 2020). We also know that some people show a bias towards interpreting actions as intentional when judging accidental or arbitrary actions of others. If an action was performed unintentionally, but the information about the intention of an action is missing, there is a tendency to label it as intentional still. This construct is called intentionality bias (Rosset, 2008). In a first rapid and automatic response to behaviour, this intentionality bias is activated, and all actions are categorised as intentional. In a second process, a deliberate, more accurate analysis can overwrite this bias in case of evidence for unintentional behaviour. According to this theory, classifying behaviour is determined not only by the skill to recognise hints for intention but mainly through the skill to identify errors of interpretation and the ability to overwrite these errors (Rosset & Rottman, 2014). Investigating the relation between intentionality bias—judging other people's sense of agency—and one's own sense of agency could clarify whether we assume that other people have the same level of control over their actions as though we feel ourselves. Or alternatively, whether we measure their actions and intentions with different standards from our own actions. This could have crucial implications for the objectivity of the judge in a court scenario.

7.9 Implications and Conclusion

Our results extended upon exciting evidence that sense of agency is responsive to emotional states (e.g. Christensen et al., 2019). These adjustments make it flexible and vulnerable at the same time. Previous studies had emphasised the importance of negative arousing states during action performance for the perception and feeling of control over actions (Christensen et al., 2019). We expanded these results to positive or ambiguous affective states such as sexual arousal and pleasure (Render et al., under review) as these are just as relevant as fear and anger in terms of motivation, underestimation of risks and engaging in reckless behaviour resulting in criminal actions (van Gelder, 2013). Interindividual differences in the sense of agency independent of emotional states were not found, although personality traits did show different pattern over time. Remarkably, the response to emotional states also interacted with personality traits which has not been observed before, traits of interest in this context were vulnerable narcissism showing an impaired feeling of control over actions and consequences in sexual arousal, trait anxiety associated with decreased feeling of control over action but increased awareness of consequences, and psychopathy which was linked disconnection to the action outcomes but intact feeling of control over actions (Render et al., under review).

Throughout we reported results for both components individually (Render et al., under review; Render & Jansen, 2020). Thus, we were able to show different responses to emotional states and in interactions with the personality traits for action and outcome binding supporting the view that they are driven by distinct mechanisms (Tanaka et al., 2019). We moreover found partial evidence that action binding is closer connected to the dopamine system: blink rates indexing dopaminergic activity and effects of sexual arousal were more pronounced for action binding than for outcome binding (Render et al., under review).

Hence, the link between personality, emotions and the feeling of control highlights that the sense of agency is part of the foundation for our society in terms of legal responsibility (Haggard, 2017; Haggard & Tsakiris, 2009; Moore, 2016). We are legally culpable for our actions, but this presupposes that we have a sense of control over our actions and that we are aware of the consequences (Haggard & Chambon, 2012). If this sense of control is disrupted, however, a partial or total exemption from criminal liability can be effective (§20 Schuldunfähigkeit wegen seelischer Störungen, §21 verminderte Schuldfaehigkeit StGB) and treatment options should be considered in a less punitive and more resource-oriented way.

References

Aarts, H., Bijleveld, E., Custers, R., Dogge, M., Deelder, M., Schutter, D., & van Haren, N. E. M. (2012). Positive priming and intentional binding: Eye-blink rate predicts reward information effects on the sense of agency. *Social Neuroscience*, *7*(1), 105–112. https://doi.org/10.1080/17470919.2011.590602

Aarts, H., & van den Bos, K. (2011). On the foundations of beliefs in free will: Intentional binding and unconscious priming in self-agency. *Psychological Science*, *22*(4), 532–537. https://doi.org/10.1177/0956797611399294

Abusharha, A. A. (2017). Changes in blink rate and ocular symptoms during different reading tasks. *Clinical Optometry*, *9*, 133–138. https://doi.org/10.2147/OPTO.S142718

Akselrod, S., Gordon, D., Ubel, F. A., Shannon, D. C., Berger, A. C., & Cohen, R. J. (1981). Power spectrum analysis of heart rate fluctuation: A quantitative probe of beat-to-beat cardiovascular control. *Science*, *213*(4504), 220–222. https://doi.org/10.1126/science.6166045

Alvarez, R. P., Kirlic, N., Misaki, M., Bodurka, J., Rhudy, J. L., Paulus, M. P., & Drevets, W. C. (2015). Increased anterior insula activity in anxious individuals is linked to diminished perceived control. *Translational Psychiatry*, *5*, e591. https://doi.org/10.1038/tp.2015.84

Anderson, N. E., Steele, V. R., Maurer, J. M., Rao, V., Koenigs, M. R., Decety, J [Jean], Kosson, D. S., Calhoun, V. D., & Kiehl, K. A. (2017). Differentiating emotional processing and attention in psychopathy with functional neuroimaging. *Cognitive, Affective & Behavioral Neuroscience*, *17*(3), 491–515. https://doi.org/10.3758/s13415-016-0493-5

Arias-Carrión, Ó., & Pöppel, E. (2007). Dopamine, learning, and reward-seeking behavior. *Acta Neurobiologiae Experimentalis*, *67*(4), 481–488.

Ariely, D., & Loewenstein, G. (2006). The heat of the moment: the effect of sexual arousal on sexual decision making. *Journal of Behavioral Decision Making*, *19*(2), 87–98. https://doi.org/10.1002/bdm.501

Asai, T., & Tanno, Y. (2008). Highly schizotypal students have a weaker sense of self-agency. *Psychiatry and Clinical Neurosciences*, *62*(1), 115–119. https://doi.org/10.1111/j.1440-1819.2007.01768.x

Ashby, F. G., Isen, A. M [A. M.], & Turken, A. U. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review*, *106*(3), 529–550. https://doi.org/10.1037/0033-295x.106.3.529

Aston-Jones, G., & Cohen, J. D. (2005). An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. *Annual Review of Neuroscience*, *28*, 403–450. https://doi.org/10.1146/annurev.neuro.28.061604.135709

Babor, T., Higgins-Biddle, J., Saunders, J., & Monteiro, M. (2001). *AUDIT: The Alkohol Use Disorder Idenfication Test* (2.th ed.).

Baess, P., Widmann, A., Roye, A., Schröger, E., & Jacobsen, T. (2009). Attenuated human auditory middle latency response and evoked 40-Hz response to self-initiated sounds. *The European Journal of Neuroscience*, *29*(7), 1514–1521. https://doi.org/10.1111/j.1460-9568.2009.06683.x

Barclay, A. M. (1969). The effect of hostility on physiological and fantasy responses. *Journal of Personality*, *37*(4), 651–667. https://doi.org/10.1111/j.1467-6494.1969.tb01771.x

Barlow, D. H [David H.], Sakheim, D. K [David K.], & Beck, J. G [J. Gayle] (1983). Anxiety increases sexual arousal. *Journal of Abnormal Psychology*, *92*(1), 49–54. https://doi.org/10.1037/0021-843X.92.1.49

Barrett, L. F. (1998). Discrete Emotions or Dimensions? The Role of Valence Focus and Arousal Focus. *Cognition & Emotion*, *12*(4), 579–599. https://doi.org/10.1080/026999398379574

Baskin-Sommers, A., Curtin, J. J., Li, W., & Newman, J. P. (2012). Psychopathy-related differences in selective attention are captured by an early event-related potential. *Personality Disorders*, *3*(4), 370–378. https://doi.org/10.1037/a0025593

Battaglia, G., Yeh, S. Y., & Souza, E. B. de (1988). MDMA-induced neurotoxicity: parameters of degeneration and recovery of brain serotonin neurons. *Pharmacology Biochemistry and Behavior*(29(2)), 269–274.

Beatty, J., & Lucero-Wagoner, B. (2000). The Pupillary System. In *Handbook of psychophysiology* (142-162).

Beck, J. G [J. G.], Barlow, D. H [D. H.], Sakheim, D. K [D. K.], & Abrahamson, D. J. (1987). Shock threat and sexual arousal: The role of selective attention, thought content, and affective states. *Psychophysiology*, *24*(2), 165–172. https://doi.org/10.1111/j.1469-8986.1987.tb00273.x

Berridge, K. C. (2007). The debate over dopamine's role in reward: The case for incentive salience. *Psychopharmacology*, *191*(3), 391–431. https://doi.org/10.1007/s00213-006-0578-x

Berry, A. S., White, R. L., Furman, D. J., Naskolnakorn, J. R., Shah, V. D., D'Esposito, M., & Jagust, W. J. (2019). Dopaminergic Mechanisms Underlying Normal Variation in Trait Anxiety. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *39*(14), 2735–2744. https://doi.org/10.1523/JNEUROSCI.2382-18.2019

Blakemore, S.-J., Wolpert, D. M [Daniel M.], & Frith, C. D. (2002). Abnormalities in the awareness of action. *Trends in Cognitive Sciences*, *6*(6), 237–242. https://doi.org/10.1016/S1364-6613(02)01907-1

Blinkhorn, V., Lyons, M., & Almond, L. (2016). Drop the bad attitude! Narcissism predicts acceptance of violent behaviour. *Personality and Individual Differences*, *98*, 157–161. https://doi.org/10.1016/j.paid.2016.04.025

Blinkhorn, V., Lyons, M., & Almond, L. (2019). Criminal Minds: Narcissism Predicts Offending Behavior in a Non-Forensic Sample. *Deviant Behavior*, *40*(3), 353–360. https://doi.org/10.1080/01639625.2017.1422458

Borhani, K., Beck, B [Brianna], & Haggard, P [Patrick] (2017). Choosing, Doing, and Controlling: Implicit Sense of Agency Over Somatosensory Events. *Psychological Science*, *28*(7), 882–893. https://doi.org/10.1177/0956797617697693

Boucsein, W. (2012). *Electrodermal Activity*. Springer US. https://doi.org/10.1007/978-1-4614-1126-0

Boucsein, W., Fowles, D. C., Grimnes, S., Ben-Shakhar, G., Roth, W. T., Dawson, M. E., & Filion, D. L. (2012). Society for psychophysiological research ad hoc committee on electrodermal measures. publication recommendations for electrodermal measurements. *Psychophysiology*, *49*(8), 1017–1034.

Bowman, J. (2016). Bowman, J. (2016). Comorbid substance use disorders and mental health disorders among New Zealand prisoners. *The New Zealand Corrections Journal*, *4*(1).

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J [Peter J.] (2001). Emotion and motivation I: Defensive and appetitive reactions in picture processing. *Emotion*, *1*(3), 276–298. https://doi.org/10.1037/1528-3542.1.3.276

Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J [Peter J.] (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology*, *45*(4), 602–607. https://doi.org/10.1111/j.1469-8986.2008.00654.x

Bradley, M. M., Sapigao, R. G., & Lang, P. J [Peter J.] (2017). Sympathetic ANS modulation of pupil diameter in emotional scene perception: Effects of hedonic content, brightness, and contrast. *Psychophysiology*, *54*(10), 1419–1435. https://doi.org/10.1111/psyp.12890

Brazil, I. A., Mars, R. B., Bulten, B. H., Buitelaar, J. K., Verkes, R. J., & Bruijn, E. R. A. de (2011). A neurophysiological dissociation between monitoring one's own and others' actions in psychopathy. *Biological Psychiatry*, *69*(7), 693–699. https://doi.org/10.1016/j.biopsych.2010.11.013

Brom, M., Both, S., Laan, E [Ellen], Everaerd, W [Walter], & Spinhoven, P. (2014). The role of conditioning, learning and dopamine in sexual behavior: A narrative review of animal and human studies. *Neuroscience and Biobehavioral Reviews*, *38*, 38–59. https://doi.org/10.1016/j.neubiorev.2013.10.014

Buckholtz, J. W., Treadway, M. T., Cowan, R. L., Woodward, N. D., Benning, S. D., Li, R., Ansari, M. S., Baldwin, R. M., Schwartzman, A. N., Shelby, E. S., Smith, C. E., Cole, D., Kessler, R. M., & Zald, D. H. (2010). Mesolimbic dopamine reward system hypersensitivity in individuals with psychopathic traits. *Nature Neuroscience*, *13*(4), 419–421. https://doi.org/10.1038/nn.2510

Burley, D. T., Gray, N. S., & Snowden, R. J. (2019). Emotional modulation of the pupil response in psychopathy. *Personality Disorders*, *10*(4), 365–375. https://doi.org/10.1037/per0000313

Carvalho, S., Leite, J., Galdo-Álvarez, S., & Gonçalves, O. F. (2012). The Emotional Movie Database (EMDB): A self-report and psychophysiological study. *Applied Psychophysiology and Biofeedback*, *37*(4), 279–294. https://doi.org/10.1007/s10484-012-9201-6

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment:: the BIS/BAS scales. *Journal of Personality and Social Psychology*, *67*(2), 319.

Caspi, A. (1998). Personality development across the life course. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology: Social, emotional, and personality development* (pp. 311–388). John Wiley & Sons Inc.

Cavanagh, J. F., Masters, S. E., Bath, K., & Frank, M. J. (2014). Conflict acts as an implicit cost in reinforcement learning. *Nature Communications*, *5*, 5394. https://doi.org/10.1038/ncomms6394

Chepenik, L. G., Cornew, L. A., & Farah, M. J. (2007). The influence of sad mood on cognition. *Emotion*, *7*(4), 802–811. https://doi.org/10.1037/1528-3542.7.4.802

Chester, D. S., DeWall, C. N., Derefinko, K. J., Estus, S., Lynam, D. R., Peters, J. R., & Jiang, Y. (2016). Looking for reward in all the wrong places: Dopamine receptor gene polymorphisms indirectly affect aggression through sensation-seeking. *Social Neuroscience*, *11*(5), 487–494. https://doi.org/10.1080/17470919.2015.1119191

Chiew, K. S., & Braver, T. S. (2011). Positive affect versus reward: Emotional and motivational influences on cognitive control. *Frontiers in Psychology*, *2*, 279. https://doi.org/10.3389/fpsyg.2011.00279

Cho, J. R., Treweek, J. B., Robinson, J. E., Xiao, C., Bremner, L. R., Greenbaum, A., & Gradinaru, V. (2017). Dorsal Raphe Dopamine Neurons Modulate Arousal and Promote Wakefulness by Salient Stimuli. *Neuron*, *94*(6), 1205-1219.e8. https://doi.org/10.1016/j.neuron.2017.05.020

Christensen, J., Di Costa, S., Beck, B [B.], & Haggard, P [P.] (2019). I just lost it! Fear and anger reduce the sense of agency: A study using intentional binding. *Experimental Brain Research*, *237*(5), 1205–1212. https://doi.org/10.1007/s00221-018-5461-6

Christensen, J., Yoshie, M [M.], Di Costa, S., & Haggard, P [P.] (2016). Emotional valence, sense of agency and responsibility: A study using intentional binding. *Consciousness and Cognition*, *43*, 1–10. https://doi.org/10.1016/j.concog.2016.02.016

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* (2nd edn). Lawrence Erlbaum Associates Inc.

Cools, R., & D'Esposito, M. (2011). Inverted-U-shaped dopamine actions on human working memory and cognitive control. *Biological Psychiatry*, *69*(12), e113-25. https://doi.org/10.1016/j.biopsych.2011.03.028

Corry, N., Merritt, R. D., Mrug, S., & Pamp, B. (2008). The factor structure of the Narcissistic Personality Inventory. *Journal of Personality Assessment*, *90*(6), 593–600. https://doi.org/10.1080/00223890802388590

Craft, N., & Schwartz, J. B. (1995). Effects of age on intrinsic heart rate, heart rate variability, and AV conduction in healthy humans. *The American Journal of Physiology*, *268*(4 Pt 2), H1441-52. https://doi.org/10.1152/ajpheart.1995.268.4.H1441

Daig, I., Burkert, S., Fischer, H. F., Kienast, T., Klapp, B. F., & Fliege, H. (2010). Development and factorial validation of a short version of the narcissism inventory (NI-20). *Psychopathology*, *43*(3), 150–158. https://doi.org/10.1159/000288636

Damasio, A. R., Grabowski, T. J., Bechara, A., Damasio, H., Ponto, L. L., Parvizi, J., & Hichwa, R. D. (2000). Subcortical and cortical brain activity during the feeling of self-generated emotions. *Nature Neuroscience*, *3*(10), 1049–1056. https://doi.org/10.1038/79871

Damsma, G., Pfaus, J. G., Wenkstern, D., Phillips, A. G., & Fibiger, H. C. (1992). Sexual behavior increases dopamine transmission in the nucleus accumbens and striatum of male rats: Comparison with novelty and locomotion. *Behavioral Neuroscience*, *106*(1), 181–191. https://doi.org/10.1037/0735-7044.106.1.181

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. Plenum.

Dennis, T. A., & Chen, C.-C. (2007). Emotional face processing and attention performance in three domains: Neurophysiological mechanisms and moderating effects of trait anxiety. *International Journal of Psychophysiology : Official Journal of the International Organization of Psychophysiology*, *65*(1), 10–19. https://doi.org/10.1016/j.ijpsycho.2007.02.006

Depue, R. A., & Collins, P. F. (1999). Neurobiology of the structure of personality:: Dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and Brain Sciences*, *22*(3), 491–517.

Dewey, J. A., & Knoblich, G. (2014). Do implicit and explicit measures of the sense of agency measure the same thing? *PloS One*, *9*(10), e110118. https://doi.org/10.1371/journal.pone.0110118

Di Pierro, R., Di Sarno, M., & Madeddu, F. (2017). Investigating the relationship between narcissism and emotion regulation difficulties:: the role of grandiose and vulnerable traits. *Clinical Neuropsychiatry*, *3*(14), 209–215.

Dickinson, K. A., & Pincus, A. L. (2003). Interpersonal analysis of grandiose and vulnerable narcissism. *Journal of Personality Disorders*, *17*(3), 188–207. https://doi.org/10.1521/pedi.17.3.188.22146

Dimaggio, G., & Lysaker, P. H. (2015). Commentary: "Personality and Intentional Binding: An Exploratory Study Using the Narcissistic Personality Inventory". *Frontiers in Human Neuroscience*, *9*, 325. https://doi.org/10.3389/fnhum.2015.00325

Ditto, P. H., Pizarro, D. A., Epstein, E. B., Jacobson, J. A., & MacDonald, T. K. (2006). Visceral influences on risk-taking behavior. *Journal of Behavioral Decision Making*, *19*(2), 99–113. https://doi.org/10.1002/bdm.520

Dreisbach, G. (2006). How positive affect modulates cognitive control: The costs and benefits of reduced maintenance capability. *Brain and Cognition*, *60*(1), 11–19. https://doi.org/10.1016/j.bandc.2005.08.003

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *30*(2), 343–353. https://doi.org/10.1037/0278-7393.30.2.343

Eisenbarth, H., Lilienfeld, S. O [Scott O.], & Yarkoni, T. (2015). Using a genetic algorithm to abbreviate the Psychopathic Personality Inventory-Revised (PPI-R). *Psychological Assessment: A Journal of Consulting and Clinical Psychology*, *27*(1), 194–202. https://doi.org/10.1037/pas0000032

Eisenberg, N [Nancy], Fabes, R. A., Guthrie, I. K., & Reiser, M. (2000). Dispositional emotionality and regulation: Their role in predicting quality of social functioning. *Journal of Personality and Social Psychology*, *78*(1), 136–157. https://doi.org/10.1037/0022-3514.78.1.136

Everaerd, W [W.], & Kirst, T. (1989). *Sexuele opwinding: een emotie [*Unpublished manuscript.].

Fadok, J. P., Dickerson, T. M. K., & Palmiter, R. D. (2009). Dopamine is necessary for cue-dependent fear conditioning. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *29*(36), 11089–11097. https://doi.org/10.1523/JNEUROSCI.1616-09.2009

Fischer, R., Lee, A., & Verzijden, M. N. (2018). Dopamine genes are linked to Extraversion and Neuroticism personality traits, but only in demanding climates. *Scientific Reports*, *8*(1), 1733. https://doi.org/10.1038/s41598-017-18784-y

Flexon, J. L., Meldrum, R. C., Young, J. T., & Lehmann, P. S. (2016). Low self-control and the Dark Triad: Disentangling the predictive power of personality traits on young adult substance use, offending and victimization. *Journal of Criminal Justice*, *46*, 159–169. https://doi.org/10.1016/j.jcrimjus.2016.05.006

Floyd, M., Garfield, A., & LaSota, M. T. (2005). Anxiety sensitivity and worry. *Personality and Individual Differences*, *38*(5), 1223–1229. https://doi.org/10.1016/j.paid.2004.08.005

Ford, J. A., & Blumenstein, L. (2013). Self-Control and Substance Use Among College Students. *Journal of Drug Issues*, *43*(1), 56–68. https://doi.org/10.1177/0022042612462216 (Journal of Drug Issues, 43(1), 56-68).

Forgas, J. P. (2014). Can sadness be good for you? On the cognitive, motivational, and interpersonal benefits of negative affect. In W. G. Parrott (Ed.), *The positive side of negative emotions* (p. 3–36). Guilford Press.

Fox, A. R., Kvaran, T. H., & Fontaine, R. G. (2013). Psychopathy and Culpability: How Responsible Is the Psychopath for Criminal Wrongdoing? *Law & Social Inquiry*, *38*(01), 1–26. https://doi.org/10.1111/j.1747-4469.2012.01294.x

Gabert-Quillen, C. A., Bartolini, E. E., Abravanel, B. T., & Sanislow, C. A. (2015). Ratings for emotion film clips. *Behavior Research Methods*, *47*(3), 773–787. https://doi.org/10.3758/s13428-014-0500-0

Gallagher, S. (2000). Philosophical conceptions of the self: Implications for cognitive science. *Trends in Cognitive Sciences*, *4*(1), 14–21. https://doi.org/10.1016/S1364-6613(99)01417-5

Gallagher, S., & Trigg, D. (2016). Agency and Anxiety: Delusions of Control and Loss of Control in Schizophrenia and Agoraphobia. *Frontiers in Human Neuroscience*, *10*, 459. https://doi.org/10.3389/fnhum.2016.00459

Garaizar, P., Cubillas, C. P., & Matute, H. (2016). A HTML5 open source tool to conduct studies based on Libet's clock paradigm. *Scientific Reports*, *6*, 32689. https://doi.org/10.1038/srep32689

Garofalo, C., Neumann, C. S., & Velotti, P. (2018). Difficulties in emotion regulation and psychopathic traits in violent offenders. *Journal of Criminal Justice*, *57*, 116–125. https://doi.org/10.1016/J.JCRIMJUS.2018.05.013 (Journal of Criminal Justice, 57, 116-125).

Geller, J. (2019). *GazeR: A Package for Processing Gaze Position and Pupil Size Data: Revised and Resubmitted.*

Gentsch, A., Schütz-Bosbach, S., Endrass, T., & Kathmann, N. (2012). Dysfunctional forward model mechanisms and aberrant sense of agency in obsessive-compulsive disorder. *Biological Psychiatry*, *71*(7), 652–659. https://doi.org/10.1016/j.biopsych.2011.12.022

Gentsch, A., & Synofzik, M. (2014). Affective coding: The emotional dimension of agency. *Frontiers in Human Neuroscience*, *8*, 608. https://doi.org/10.3389/fnhum.2014.00608

George, M. S., Ketter, T. A., Parekh, P. I., Horwitz, B., Herscovitch, P., & Post, R. M. (1995). Brain activity during transient sadness and happiness in healthy women. *American Journal of Psychiatry*, *152*(3), 341–351.

Giuliano, F., & Allard, J. (2001). Dopamine and sexual function. *International Journal of Impotence Research*, *13 Suppl 3*, S18-28. https://doi.org/10.1038/sj.ijir.3900719

Given-Wilson, Z., McIlwain, D., & Warburton, W. (2011). Meta-cognitive and interpersonal difficulties in overt and covert narcissism. *Personality and Individual Differences*, *50*(7), 1000–1005. https://doi.org/10.1016/j.paid.2011.01.014

Gore, W. L., & Widiger, T. A. (2016). Fluctuation between grandiose and vulnerable narcissism. *Personality Disorders*, *7*(4), 363–371. https://doi.org/10.1037/per0000181

Graham, K. T., Martin-Iverson, M. T., & Waters, F. A. v. (2015). Intentional binding or perceptual repulsion? Binding in a general population sample decreases with age and increases with psychosis-like experiences. *Psychology of Consciousness: Theory, Research, and Practice*, *2*(3), 269–282. https://doi.org/10.1037/cns0000067

Gray, J. A. (1970). The psychophysiological basis of introversion-extraversion. *Behaviour Research and Therapy*, *8*(3), 249–266. https://doi.org/10.1016/0005-7967(70)90069-0 (Behaviour Research and Therapy, 8(3), 249-266).

Groat, L. L., & Shane, M. S. (2020). A Motivational Framework for Psychopathy: Toward a Reconceptualization of the Disorder. *European Psychologist*, *25*(2), 92–103. https://doi.org/10.1027/1016-9040/a000394

Haggard, P [P.] (2017). Sense of agency in the human brain. *Nature Reviews. Neuroscience*, *18*(4), 196–207. https://doi.org/10.1038/nrn.2017.14

Haggard, P [P.], & Chambon, V. (2012). Sense of agency. *Current Biology*, *22*(10), R390-R392.

Haggard, P [P.], Clark, S., & Kalogeras, J. (2002). Voluntary action and conscious awareness. *Nature Neuroscience*, *5*(4), 382–385. https://doi.org/10.1038/nn827

Haggard, P [P.], Martin, F., Taylor-Clarke, M., Jeannerod, M., & Franck, N. (2003). Awareness of action in schizophrenia. *Neuroreport*, *14*(7), 1081–1085. https://doi.org/10.1097/01.wnr.0000073684.00308.c0

Haggard, P [P.], & Tsakiris, M. (2009). The Experience of Agency. *Current Directions in Psychological Science*, *18*(4), 242–246. https://doi.org/10.1111/j.1467-8721.2009.01644.x

Hamann, S., & Canli, T. (2004). Individual differences in emotion processing. *Current Opinion in Neurobiology*, *14*(2), 233–238. https://doi.org/10.1016/j.conb.2004.03.010

Hanoch, Y., & Vitouch, O. (2004). When less is more. *Theory & Psychology*, *14*(4), 427–452. https://doi.org/10.1177/0959354304044918 (Theory & Psychology, 14(4), 427-452).

Hansen-Brown, A. A. (2018). Perceived Control Theory of Narcissism. In A. D. Hermann, A. B. Brunell, & J. D. Foster (Eds.), *Handbook of Trait Narcissism* (pp. 27–35). Springer International Publishing. https://doi.org/10.1007/978-3-319-92171-6_3

Hare, R. D., Clark, D., Grann, M., & Thornton, D. (2000). Psychopathy and the predictive validity of the PCL-R: an international perspective. *Behavioral Sciences & the Law*, *18*(5), 623–645. https://doi.org/10.1002/1099-0798(200010)18:5<623::AID-BSL409>3.0.CO;2-W

Harkins, L., & Beech, A. R. (2007). A review of the factors that can influence the effectiveness of sexual offender treatment: Risk, need, responsivity, and process issues. *Aggression and Violent Behavior*, *12*(6), 615–627. https://doi.org/10.1016/j.avb.2006.10.006

Hascalovitz, A. C., & Obhi, S. S. (2015). Personality and intentional binding: An exploratory study using the narcissistic personality inventory. *Frontiers in Human Neuroscience*, *9*, 13. https://doi.org/10.3389/fnhum.2015.00013

Hauser, M., Moore, J [J.], Millas, W. de, Gallinat, J., Heinz, A., Haggard, P [P], & Voss, M. (2011). Sense of agency is altered in patients with a putative psychotic prodrome. *Schizophrenia Research*, *126*(1-3), 20–27. https://doi.org/10.1016/j.schres.2010.10.031

Hecker, J. E., King, M. W., & Scoular, R. J. (2009). The startle probe reflex: An alternative approach to the measurement of sexual interest. In David Thornton, D. Richard Laws (Ed.), *Cognitive approaches to the assessment of sexual interest in sexual offenders* (pp. 59–84). https://doi.org/10.1002/9780470747551

Heiman, J. R. (1977). A psychophysiological exploration of sexual arousal patterns in females and males. *Psychophysiology*, *14*(3), 266–274. https://doi.org/10.1111/j.1469-8986.1977.tb01173.x

Herman, A. M., & Tsakiris, M. (2020). Feeling in Control: The Role of Cardiac Timing in the Sense of Agency. *Affective Science*. Advance online publication. https://doi.org/10.1007/s42761-020-00013-x

Hertzog, C., & Nesselroade, J. R. (1987). Beyond Autoregressive Models: Some Implications of the Trait-State Distinction for the Structural Modeling of Developmental Change. *Child Development*, *58*(1), 93. https://doi.org/10.2307/1130294

Holmes, A. J., Hollinshead, M. O., Roffman, J. L., Smoller, J. W., & Buckner, R. L. (2016). Individual Differences in Cognitive Control Circuit Anatomy Link Sensation Seeking, Impulsivity, and Substance Use. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *36*(14), 4038–4049. https://doi.org/10.1523/JNEUROSCI.3206-15.2016

Hoon, P. W., Wincze, J. P., & Hoon, E. F. (1977). A test of reciprocal inhibition: Are anxiety and sexual arousal in women mutually inhibitory? *Journal of Abnormal Psychology*, *86*(1), 65–74. https://doi.org/10.1037/0021-843X.86.1.65

Horváth, J. (2015). Action-related auditory ERP attenuation: Paradigms and hypotheses. *Brain Research*, *1626*, 54–65. https://doi.org/10.1016/j.brainres.2015.03.038

Hughes, G., Desantis, A., & Waszak, F. (2013). Mechanisms of intentional binding and sensory attenuation: The role of temporal prediction, temporal control, identity prediction, and motor prediction. *Psychological Bulletin*, *139*(1), 133–151. https://doi.org/10.1037/a0028566

Humphreys, G. R., & Buehner, M. J. (2009). Magnitude estimation reveals temporal binding at super-second intervals. *Journal of Experimental Psychology. Human Perception and Performance*, *35*(5), 1542–1549. https://doi.org/10.1037/a0014492

Humphreys, G. R., & Buehner, M. J. (2010). Temporal binding of action and effect in interval reproduction. *Experimental Brain Research*, *203*(2), 465–470. https://doi.org/10.1007/s00221-010-2199-1

Hur, J.-W., Kwon, J. S., Lee, T. Y., & Park, S. (2014). The crisis of minimal self-awareness in schizophrenia: A meta-analytic review. *Schizophrenia Research*, *152*(1), 58–64. https://doi.org/10.1016/j.schres.2013.08.042

Jakšić, N., Milas, G., Ivezić, E., Wertag, A., Jokić-Begić, N., & Pincus, A. L. (2014). The Pathological Narcissism Inventory (PNI) in Transitional Post-War Croatia: Psychometric and Cultural Considerations. *Journal of Psychopathology and Behavioral Assessment*, *36*(4), 640–652. https://doi.org/10.1007/s10862-014-9425-2

Jennings, J. R., Berg, W. K., Hutcheson, J. S., Obrist, P., Porges, S., & Turpin, G. (1981). Committee report. Publication guidelines for heart rate studies in man. *Psychophysiology*, *18*(3), 226–231. https://doi.org/10.1111/j.1469-8986.1981.tb03023.x

John, O. P., & Gross, J. J [James J.] (2004). Healthy and unhealthy emotion regulation: Personality processes, individual differences, and life span development. *Journal of Personality*, *72*(6), 1301–1333. https://doi.org/10.1111/j.1467-6494.2004.00298.x

Jones, L. A., Hills, P. J., Dick, K. M., Jones, S. P., & Bright, P. (2016). Cognitive mechanisms associated with auditory sensory gating. *Brain and Cognition*, *102*, 33–45. https://doi.org/10.1016/j.bandc.2015.12.005

Jongkees, B. J., & Colzato, L. S. (2016). Spontaneous eye blink rate as predictor of dopamine-related cognitive function-A review. *Neuroscience and Biobehavioral Reviews*, *71*, 58–82. https://doi.org/10.1016/j.neubiorev.2016.08.020

Karama, S., Lecours, A. R., Leroux, J.-M., Bourgouin, P., Beaudoin, G., Joubert, S., & Beauregard, M. (2002). Areas of brain activation in males and females during viewing of erotic film excerpts. *Human Brain Mapping*, *16*(1), 1–13.

Karcum, F., Suddath, R. L., & Wyatt, R. J. (1990). Chronic cocaine and rat brain catecholamines: long-term reduction in hypothalamic and frontal cortex dopamine metabolism. *European Journal of Pharmacology*, *186*(1), 1–8. https://doi.org/10.1016/0014-2999(90)94054-2

Keil, A., & Ihssen, N. (2004). Identification facilitation for emotionally arousing verbs during the attentional blink. *Emotion*, *4*(1), 23–35. https://doi.org/10.1037/1528-3542.4.1.23

Kelley, S. E., Edens, J. F., Donnellan, M. B., Ruchensky, J. R., Witt, E. A., & McDermott, B. E. (2016). Development and validation of an inconsistent responding scale for an abbreviated version of the Psychopathic Personality Inventory — Revised. *Personality and Individual Differences*, *91*, 58–62. https://doi.org/10.1016/j.paid.2015.11.033

Knight, R. A [R. A.], & Guay, J. P. (2006). The Role of Psychopathy in Sexual Coercion against Women.

Kober, H. (2014). Emotion regulation in substance use disorders. In J. J. Gross (Ed.), *Handbook of emotion regulation*. The Guilford Press.

Köhler, D., Heinzen, H., Hinrichs, G., & Huchzermeier, C. (2009). The prevalence of mental disorders in a German sample of male incarcerated juvenile offenders. *International Journal of Offender Therapy and Comparative Criminology*, *53*(2), 211–227. https://doi.org/10.1177/0306624X07312950

Kokkonen, M., & Pulkkinen, L. (2001). Examination of the paths between personality, current mood, its evaluation, and emotion regulation. *European Journal of Personality*, *15*(2), 83–104. https://doi.org/10.1002/per.397

Koob, G. F., & Le Moal, M. (1997). Drug Abuse: Hedonic Homeostatic Dysregulation. *Science*, *278*(5335), 52–58. https://doi.org/10.1126/science.278.5335.52

Kosson, D. S., Smith, S. S., & Newman, J. P. (1990). Evaluating the construct validity of psychopathy in Black and White male inmates: Three preliminary studies. *Journal of Abnormal Psychology*, *99*(3), 250–259. https://doi.org/10.1037/0021-843X.99.3.250

Koster, E. H. W., Crombez, G., Verschuere, B., van Damme, S., & Wiersema, J. R. (2006). Components of attentional bias to threat in high trait anxiety: Facilitated engagement, impaired disengagement, and attentional avoidance. *Behaviour Research and Therapy*, *44*(12), 1757–1771. https://doi.org/10.1016/j.brat.2005.12.011

Kraus, L., Leifman, H., Vicente, J., Guttormsson, U., Molinaro, S., & Arpa, S. (2016). *ESPAD Report 2015: Results from the European School Survey Project on Alcohol and Other Drugs*. *ESPAD Report: Vol. 2015*. Publications Office of the European Union.

Kret, M. E., & Sjak-Shie, E. E. (2019). Preprocessing pupil size data: Guidelines and code. *Behavior Research Methods*, *51*(3), 1336–1342. https://doi.org/10.3758/s13428-018-1075-y

Kubarych, T. S., Deary, I. J., & Austin, E. J. (2004). The Narcissistic Personality Inventory: factor structure in a non-clinical sample. *Personality and Individual Differences*, *36*(4), 857–872. https://doi.org/10.1016/S0191-8869(03)00158-2

Laakso, A., Wallius, E., Kajander, J., Bergman, J., Eskola, O., Solin, O., Ilonen, T., Salokangas, R. K. R., Syvälahti, E., & Hietala, J. (2003). Personality traits and striatal dopamine synthesis capacity in healthy subjects. *The American Journal of Psychiatry*, *160*(5), 904–910. https://doi.org/10.1176/appi.ajp.160.5.904

Laan, E [E.], Everaerd, W [W.], & Evers, A. (1995). Assessment of female sexual arousal: Response specificity and construct validity. *Psychophysiology*, *32*(5), 476–485. https://doi.org/10.1111/j.1469-8986.1995.tb02099.x

Lang, P. J [P. J.] (Ed.). (1980). *Behavioral treatment and bio-behavioral assessment: Computer applications.*

Laurell, J., & Dåderman, A. M. (2005). Recidivism is related to psychopathy (PCL-R) in a group of men convicted of homicide. *International Journal of Law and Psychiatry*, *28*(3), 255–268. https://doi.org/10.1016/j.ijlp.2004.08.008

Leue, A., Borchard, B., & Hoyer, J. (2004). Mental disorders in a forensic sample of sexual offenders. *European Psychiatry : The Journal of the Association of European Psychiatrists*, *19*(3), 123–130. https://doi.org/10.1016/j.eurpsy.2003.08.001

Levenston, G. K., Patrick, C. J., Bradley, M. M., & Lang, P. J [Peter J.] (2000). The psychopath as observer: Emotion and attention in picture processing. *Journal of Abnormal Psychology*, *109*(3), 373–385. https://doi.org/10.1037/0021-843X.109.3.373

Lilienfeld, S. O [S. O.], & Andrews, B. P. (1996). Development and preliminary validation of a self-report measure of psychopathic personality traits in noncriminal populations. *Journal of Personality Assessment*, *66*(3), 488–524. https://doi.org/10.1207/s15327752jpa6603_3

Lilienfeld, S. O [S. O.], & Arkowitz, H. (2007). What "Psychopath" Means. *Scientific American Mind*, *18*(6), 80–81. https://doi.org/10.1038/scientificamericanmind1207-80

Lilienfeld, S. O [S. O.], & Widows, M. R. (2005). *Psychological assessment inventory-revised (PPI-R)*. Psychological Assessment Resources.

Lüdecke, D. (2018). *Sjstats: Statistical Functions For Regression Models* [Computer software]. Zenodo.

Lush, P., Roseboom, W., Cleeremans, A., Scott, R. B., Seth, A. K., & Dienes, Z. (2019). Intentional binding as Bayesian cue combination: Testing predictions with trait individual differences. *Journal of Experimental Psychology. Human Perception and Performance*, *45*(9), 1206–1217. https://doi.org/10.1037/xhp0000661

Lutz, J., & Krahé, B. (2018). Inducing sadness reduces anger-driven aggressive behavior: A situational approach to aggression control. *Psychology of Violence*, *8*(3), 358–366. https://doi.org/10.1037/vio0000167

Maffei, A., & Angrilli, A. (2018). Spontaneous eye blink rate: An index of dopaminergic component of sustained attention and fatigue. *International Journal of Psychophysiology : Official Journal of the International Organization of Psychophysiology*, *123*, 58–63. https://doi.org/10.1016/j.ijpsycho.2017.11.009

Maffei, A., & Angrilli, A. (2019). Spontaneous blink rate as an index of attention and emotion during film clips viewing. *Physiology & Behavior*, *204*, 256–263. https://doi.org/10.1016/j.physbeh.2019.02.037

Marona-Lewicka, D., Thisted, R. A., & Nichols, D. E. (2005). Distinct temporal phases in the behavioral pharmacology of LSD: Dopamine D2 receptor-mediated effects in the rat and implications for psychosis. *Psychopharmacology*, *180*(3), 427–435. https://doi.org/10.1007/s00213-005-2183-9

Marshall, A. C., Gentsch, A., & Schütz-Bosbach, S. (2018). The Interaction between Interoceptive and Action States within a Framework of Predictive Coding. *Frontiers in Psychology*, *9*, 180. https://doi.org/10.3389/fpsyg.2018.00180

Marshall, W. L., Laws, D. R., & Barbaree, H. E. (Eds.). (1990). *Handbook of sexual assault:: Issues, theories, and treatment of the offender*. Plenum.

Mather, M., & Sutherland, M. R. (2011). Arousal-Biased Competition in Perception and Memory. *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, *6*(2), 114–133. https://doi.org/10.1177/1745691611400234

Mathias, C. W., & Stanford, M. S. (2003). Impulsiveness and arousal: heart rate under conditions of rest and challenge in healthy males. *Personality and Individual Differences*, *35*(2), 355–371. https://doi.org/10.1016/S0191-8869(02)00195-2

Mathôt, S. (2018). Pupillometry: Psychology, Physiology, and Function. *Journal of Cognition*, *1*(1), 16. https://doi.org/10.5334/joc.18

Mathôt, S., Fabius, J., van Heusden, E., & van der Stigchel, S. (2018). Safe and sensible preprocessing and baseline correction of pupil-size data. *Behavior Research Methods*, *50*(1), 94–106. https://doi.org/10.3758/s13428-017-1007-2

The MathWorks Inc. (2018). *MATLAB* (Version 9.7.0.1190202 (R2019b).) [Computer software]. Natick, Massachusetts.

McCrae, R. R., Costa, P. T., Ostendorf, F., Angleitner, A., Hřebíčková, M., Avia, M. D., Sanz, J., Sánchez-Bernardos, M. L., Kusdil, M. E., Woodfield, R., Saunders, P. R., & Smith, P. B. (2000).

Nature over nurture: Temperament, personality, and life span development. *Journal of Personality and Social Psychology*, *78*(1), 173–186. https://doi.org/10.1037/0022-3514.78.1.173

McRaney, D. (2013). *You can beat your brain: How to turn your enemies into friends, how to make better decisions, and other ways to be less dumb / David McRaney*. Oneworld. https://books.google.de/books?id=tBu9DwAAQBAJ

Mendelowitz, D. (1999). Advances in Parasympathetic Control of Heart Rate and Cardiac Function. *News in Physiological Sciences : An International Journal of Physiology Produced Jointly by the International Union of Physiological Sciences and the American Physiological Society*, *14*, 155–161. https://doi.org/10.1152/physiologyonline.1999.14.4.155

Mennin, D. S., McLaughlin, K. A., & Flanagan, T. J. (2009). Emotion regulation deficits in generalized anxiety disorder, social anxiety disorder, and their co-occurrence. *Journal of Anxiety Disorders*, *23*(7), 866–871. https://doi.org/10.1016/j.janxdis.2009.04.006

Miles, G. J., Smyrnios, K. X., Jackson, M., & Francis, A. J. (2019). Reward-punishment sensitivity bias predicts narcissism subtypes: Implications for the etiology of narcissistic personalities. *Personality and Individual Differences*, *141*, 143–151. https://doi.org/10.1016/j.paid.2019.01.004

Miller, D. T., & Ross, M. (1975). Self-serving biases in the attribution of causality: Fact or fiction? *Psychological Bulletin*, *82*(2), 213–225. https://doi.org/10.1037/h0076486

Miller, J. D., Gentile, B., Wilson, L., & Campbell, W. K [W. Keith] (2013). Grandiose and vulnerable narcissism and the DSM-5 pathological personality trait model. *Journal of Personality Assessment*, *95*(3), 284–290. https://doi.org/10.1080/00223891.2012.685907

Miller, J. D., Hoffman, B. J., Gaughan, E. T., Gentile, B., Maples, J [Jessica], & Keith Campbell, W. (2011). Grandiose and vulnerable narcissism: A nomological network analysis. *Journal of Personality*, *79*(5), 1013–1042. https://doi.org/10.1111/j.1467-6494.2010.00711.x

Miller, J. D., & Maples, J [J.]. (2011). Trait personality models of narcissistic personality disorder, grandiose narcissism, and vulnerable narcissism. The handbook of narcissism and narcissistic personality disorder:: Theoretical approaches, empirical findings, and treatments. In W. K. Campbell & J. D. Miller (Eds.), *The handbook of narcissism and narcissistic personality disorder: Theoretical approaches, empirical findings, and treatments / W. Keith Campbell and Joshua D. Miller* (71-88.). John Wiley & Sons.

Moore, J [J.] (2016). What Is the Sense of Agency and Why Does it Matter? *Frontiers in Psychology*, *7*, 1272. https://doi.org/10.3389/fpsyg.2016.01272

Moore, J [J.], Cambridge, V. C., Morgan, H., Giorlando, F., Adapa, R [R.], & Fletcher, P. C [P. C.] (2013). Time, action and psychosis: Using subjective time to investigate the effects of ketamine on sense of agency. *Neuropsychologia*, *51*(2), 377–384. https://doi.org/10.1016/j.neuropsychologia.2012.07.005

Moore, J [J.], & Haggard, P [Patrick] (2008). Awareness of action: Inference and prediction. *Consciousness and Cognition*, *17*(1), 136–144. https://doi.org/10.1016/j.concog.2006.12.004

Moore, J [J.], Middleton, D., Haggard, P [P.], & Fletcher, P. C [P. C.] (2012). Exploring implicit and explicit aspects of sense of agency. *Consciousness and Cognition*, *21*(4), 1748–1753. https://doi.org/10.1016/j.concog.2012.10.005

Moore, J [J.], & Obhi, S. S. (2012). Intentional binding and the sense of agency: A review. *Consciousness and Cognition*, *21*(1), 546–561. https://doi.org/10.1016/j.concog.2011.12.002

Moore, J [J.], Schneider, S. A., Schwingenschuh, P., Moretto, G., Bhatia, K. P., & Haggard, P [P.] (2010). Dopaminergic medication boosts action-effect binding in Parkinson's disease. *Neuropsychologia*, *48*(4), 1125–1132. https://doi.org/10.1016/j.neuropsychologia.2009.12.014

Moore, J [J.], Turner, D. C., Corlett, P. R., Arana, F. S., Morgan, H. L., Absalom, A. R., Adapa, R [Ram], Wit, S. de, Everitt, J. C., Gardner, J. M., Pigott, J. S., Haggard, P [P.], & Fletcher, P. C [Paul C.] (2011). Ketamine administration in healthy volunteers reproduces aberrant agency experiences associated with schizophrenia. *Cognitive Neuropsychiatry*, *16*(4), 364–381. https://doi.org/10.1080/13546805.2010.546074

Moore, J [J.], Wegner, D. M., & Haggard, P [Patrick] (2009). Modulating the sense of agency with external cues. *Consciousness and Cognition*, *18*(4), 1056–1064. https://doi.org/10.1016/j.concog.2009.05.004

Most, S. B., Smith, S. D., Cooter, A. B., Levy, B. N., & Zald, D. H. (2007). The naked truth: Positive, arousing distractors impair rapid target perception. *Cognition & Emotion*, *21*(5), 964–981. https://doi.org/10.1080/02699930600959340

Narendran, R., Frankle, W. G., Keefe, R., Gil, R., Martinez, D., Slifstein, M., Kegeles, L. S., Talbot, P. S., Huang, Y., Hwang, D.-R., Khenissi, L., Cooper, T. B., Laruelle, M., & Abi-Dargham, A. (2005). Altered prefrontal dopaminergic function in chronic recreational ketamine users. *The American Journal of Psychiatry*, *162*(12), 2352–2359. https://doi.org/10.1176/appi.ajp.162.12.2352

Neumann, C. S., Johansson, P. T., & Hare, R. D. (2013). The Psychopathy Checklist-Revised (PCL-R), low anxiety, and fearlessness: A structural equation modeling analysis. *Personality Disorders*, *4*(2), 129–137. https://doi.org/10.1037/a0027886

Ng, W., & Diener, E. (2009). Personality Differences in Emotions. *Journal of Individual Differences*, *30*(2), 100–106. https://doi.org/10.1027/1614-0001.30.2.100

Nichols, C. (2002). A Single Dose of Lysergic Acid Diethylamide Influences Gene Expression Patterns within the Mammalian Brain. *Neuropsychopharmacology*, *26*(5), 634–642. https://doi.org/10.1016/S0893-133X(01)00405-5

Nyström, M., Hooge, I., & Andersson, R. (2016). Pupil size influences the eye-tracker signal during saccades. *Vision Research*, *121*, 95–103. https://doi.org/10.1016/j.visres.2016.01.009

Oei, N. Y. L., Rombouts, S. A., Soeter, R. P., van Gerven, J. M., & Both, S. (2012). Dopamine modulates reward system activity during subconscious processing of sexual stimuli. *Neuropsychopharmacology : Official Publication of the American College of Neuropsychopharmacology*, *37*(7), 1729–1737. https://doi.org/10.1038/npp.2012.19

Ogloff, J. R. P., Wong, S., & Greenwood, A. (1990). Treating criminal psychopaths in a therapeutic community program. *Behavioral Sciences & the Law*, *8*(2), 181–190. https://doi.org/10.1002/bsl.2370080210

O'Leary, M. M., Taylor, J., & Eckel, L. (2010). Psychopathic personality traits and cortisol response to stress: The role of sex, type of stressor, and menstrual phase. *Hormones and Behavior*, *58*(2), 250–256. https://doi.org/10.1016/j.yhbeh.2010.03.009

Osumi, T., & Ohira, H. (2010). The positive side of psychopathy: Emotional detachment in psychopathy and rational decision-making in the ultimatum game. *Personality and Individual Differences*, *49*(5), 451–456. https://doi.org/10.1016/j.paid.2010.04.016

Oswald, W. D., & Roth, E. (1987). *Der Zahlen-Verbindungs-Test (ZVT).* Hogrefe Verlag für Psychologie.

Partala, T., & Surakka, V. (2003). Pupil size variation as an indication of affective processing. *International Journal of Human-Computer Studies*, *59*(1-2), 185–198. https://doi.org/10.1016/S1071-5819(03)00017-X

Patrick, C. J., & Drislane, L. E. (2015). Triarchic Model of Psychopathy: Origins, Operationalizations, and Observed Linkages with Personality and General Psychopathology. *Journal of Personality*, *83*(6), 627–643. https://doi.org/10.1111/jopy.12119

Peifer, C., Schulz, A., Schächinger, H., Baumann, N., & Antoni, C. H. (2014). The relation of flow-experience and physiological arousal under stress — Can u shape it? *Journal of Experimental Social Psychology*, *53*, 62–69. https://doi.org/10.1016/j.jesp.2014.01.009

Peterson, Z. D., & Janssen, E. (2007). Ambivalent affect and sexual response: The impact of co-occurring positive and negative emotions on subjective and physiological sexual responses to erotic stimuli. *Archives of Sexual Behavior*, *36*(6), 793–807. https://doi.org/10.1007/s10508-006-9145-0

Philippot, P. (1993). Inducing and assessing differentiated emotion-feeling states in the laboratory. *Cognition & Emotion*, *7*(2), 171–193. https://doi.org/10.1080/02699939308409183

Pincus, A. L., Ansell, E. B., Pimentel, C. A., Cain, N. M., Wright, A. G. C., & Levy, K. N. (2009). Initial construction and validation of the Pathological Narcissism Inventory. *Psychological Assessment: A Journal of Consulting and Clinical Psychology*, *21*(3), 365–379. https://doi.org/10.1037/a0016530

Pincus, A. L., Cain, N. M., & Wright, A. G. C. (2014). Narcissistic grandiosity and narcissistic vulnerability in psychotherapy. *Personality Disorders*, *5*(4), 439–443. https://doi.org/10.1037/per0000031

Pockett, S., & Miller, A. (2007). The rotating spot method of timing subjective events. *Consciousness and Cognition*, *16*(2), 241–254. https://doi.org/10.1016/j.concog.2006.09.002

Ponseti, J., Bosinski, H. A., Wolff, S., Peller, M., Jansen, O., Mehdorn, H. M., Büchel, C., & Siebner, H. R. (2006). A functional endophenotype for sexual orientation in humans. *NeuroImage*, *33*(3), 825–833. https://doi.org/10.1016/j.neuroimage.2006.08.002

Poon, J. A., Turpyn, C. C., Hansen, A., Jacangelo, J., & Chaplin, T. M. (2016). Adolescent Substance Use & Psychopathology: Interactive Effects of Cortisol Reactivity and Emotion Regulation. *Cognitive Therapy and Research*, *40*(3), 368–380. https://doi.org/10.1007/s10608-015-9729-x

Poonian, S. K., & Cunnington, R. (2013). Intentional binding in self-made and observed actions. *Experimental Brain Research*, *229*(3), 419–427. https://doi.org/10.1007/s00221-013-3505-5

Porter, S., Campbell, M. A., Woodworth, M., & Birt, A. R. (2001). A new psychological conceptualization of the sexual psychopath. *Advances in Psychology Research*, *7*, 21–36.

Rae, C. L., Botan, V. E., van Gould Praag, C. D., Herman, A. M., Nyyssönen, J. A. K., Watson, D. R., Duka, T., Garfinkel, S. N., & Critchley, H. D. (2018). Response inhibition on the stop signal task improves during cardiac contraction. *Scientific Reports*, *8*(1), 9136. https://doi.org/10.1038/s41598-018-27513-y

Ramzan, N., Palke, S., Cuntz, T., Gibson, R., & Amira, A. (2016). Emotion Recognition by Physiological Signals. *Electronic Imaging*, *2016*(16), 1–6. https://doi.org/10.2352/ISSN.2470-1173.2016.16.HVEI-129

Raskin, R. N., & Hall, C. S. (1979). A narcissistic personality inventory. *Psychological Reports*, *45*(2), 590. https://doi.org/10.2466/pr0.1979.45.2.590

Raskin, R. N., & Terry, H. (1988). A principal-components analysis of the Narcissistic Personality Inventory and further evidence of its construct validity. *Journal of Personality and Social Psychology*, *54*(5), 890–902. https://doi.org/10.1037/0022-3514.54.5.890

Reddish, P., Tong, E. M. W., Jong, J., & Whitehouse, H. (2020). Interpersonal synchrony affects performers' sense of agency. *Self and Identity*, *19*(4), 389–411. https://doi.org/10.1080/15298868.2019.1604427

Render, A., Eisenbarth, H., Oxner, M., & Jansen, P. (under review). Forbidden Temptation—The Influence of Motivational States on Sense of Agency, moderated by Psychopathy and Trait Anxiety.

Render, A., & Jansen, P. (2019). Dopamine and sense of agency: Determinants in personality and substance use. *PloS One*, *14*(3), e0214069. https://doi.org/10.1371/journal.pone.0214069

Render, A., & Jansen, P. (2020). Influence of Arousal on Intentional Binding: Intact action binding, impaired outcome binding. *Attention, Perception & Psychophysics Journal*, 1–11. https://doi.org/10.3758/s13414-020-02105-z

Ricaurte, G. A., Martello, A. L., Katz, J. L., & Martello, M. B. (1992). Lasting effects of (+-)-3,4-methylenedioxymethamphetamine (MDMA) on central serotonergic neurons in nonhuman primates: Neurochemical observations. *The Journal of Pharmacology and Experimental Therapeutics*, *261*(2), 616–622.

Ricaurte, G. A., Seiden, L. S., & Schuster, C. R. (1984). Further evidence that amphetamines produce long-lasting dopamine neurochemical deficits by destroying dopamine nerve fibers. *Brain Research*, *303*(2), 359–364. https://doi.org/10.1016/0006-8993(84)91221-6

Rigoni, D., Demanet, J., & Sartori, G. (2015). Happiness in action: The impact of positive affect on the time of the conscious intention to act. *Frontiers in Psychology*, *6*, 1307. https://doi.org/10.3389/fpsyg.2015.01307

Roemer, L., Williston, S. K., & Rollins, L. G. (2015). Mindfulness and emotion regulation. *Current Opinion in Psychology*, *3*, 52–57. https://doi.org/10.1016/J.COPSYC.2015.02.006 (Current Opinion in Psychology, 3, 52-57).

Ronningstam, E. (2009). Narcissistic Personality Disorder: Facing DSM-V. *Psychiatric Annals*, *39*(3), 111–121. https://doi.org/10.3928/00485713-20090301-09

Rosen, R. C., & Beck, J. G [J. G.]. (1988). *Patterns of sexual arousal:: Psychophysiological processes and clinical applications.* Guilford Press.

Rosset, E. (2008). It's no accident: Our bias for intentional explanations. *Cognition*, *108*(3), 771–780. https://doi.org/10.1016/j.cognition.2008.07.001.

Rosset, E., & Rottman, J. (2014). The Big 'Whoops!' in the Study of Intentional Behavior: An Appeal for a New Framework in Understanding Human Actions. *Journal of Cognition and Culture*, *14*(1-2), 27–39. https://doi.org/10.1163/15685373-12342108

Rowland, D. L., & Uribe, D. (2020). Pornography Use: What Do Cross-Cultural Patterns Tell Us? In D. L. Rowland & E. A. Jannini (Eds.), *Trends in Andrology and Sexual Medicine. Cultural Differences and the Practice of Sexual Medicine* (pp. 317–334). Springer International Publishing. https://doi.org/10.1007/978-3-030-36222-5_18

Ruchensky, J. R., Edens, J. F., Donnellan, M. B., & Witt, E. A. (2017). Examining the reliability and validity of an abbreviated Psychopathic Personality Inventory-Revised (PPI-R) in four samples. *Psychological Assessment: A Journal of Consulting and Clinical Psychology*, *29*(2), 238–244. https://doi.org/10.1037/pas0000335

Rupp, H. A., & Wallen, K. (2008). Sex differences in response to visual sexual stimuli: A review. *Archives of Sexual Behavior*, *37*(2), 206–218. https://doi.org/10.1007/s10508-007-9217-9

Russell, J. A., Weiss, Anna,Mendelsohn, & Gerald A. (1989). Affect Grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology*, *57*(3), 493–502.

Sadeh, N., & Verona, E. (2013). Erratum to: Visual complexity attenuates emotional processing in psychopathy: implications for fear-potentiated startle deficits. *Cognitive, Affective, & Behavioral Neuroscience*, *13*(3), 584–585. https://doi.org/10.3758/s13415-013-0163-9

Saito, N., Takahata, K., Murai, T., & Takahashi, H. (2015). Discrepancy between explicit judgement of agency and implicit feeling of agency: Implications for sense of agency and its disorders. *Consciousness and Cognition*, *37*, 1–7. https://doi.org/10.1016/j.concog.2015.07.011

Saito, N., Takahata, K., Yamakado, H., Sawamoto, N., Saito, S., Takahashi, R., Murai, T., & Takahashi, H. (2017). Altered awareness of action in Parkinson's disease: Evaluations by explicit and implicit measures. *Scientific Reports*, *7*(1), 8019. https://doi.org/10.1038/s41598-017-08482-0

Sato, A. (2008). Action observation modulates auditory perception of the consequence of others' actions. *Consciousness and Cognition*, *17*(4), 1219–1227. https://doi.org/10.1016/j.concog.2008.01.003

Schultz, W. (2002). Getting Formal with Dopamine and Reward. *Neuron*, *36*(2), 241–263. https://doi.org/10.1016/S0896-6273(02)00967-4

Schultz, W., Dayan, P., & Montague, P. R. (1997). A neural substrate of prediction and reward. *Science*, *275*(5306), 1593–1599. https://doi.org/10.1126/science.275.5306.1593

Schultz, W., & Dickinson, A. (2000). Neuronal coding of prediction errors. *Annual Review of Neuroscience*, *23*, 473–500. https://doi.org/10.1146/annurev.neuro.23.1.473

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *27*(5), 1082–1089. https://doi.org/10.1523/JNEUROSCI.3223-06.2007

Seth, A. K., & Tsakiris, M. (2018). Being a Beast Machine: The Somatic Basis of Selfhood. *Trends in Cognitive Sciences*, *22*(11), 969–981. https://doi.org/10.1016/j.tics.2018.08.008

Sheth, B. R., & Pham, T. (2008). How emotional arousal and valence influence access to awareness. *Vision Research*, *48*(23-24), 2415–2424. https://doi.org/10.1016/j.visres.2008.07.013

Skakoon-Sparling, S., & Cramer, K. M. (2016). The impact of sexual arousal on elements of sexual decision making: Sexual self-restraint, motivational state, and self-control. *The Canadian Journal of Human Sexuality*, *25*(2), 119–125. https://doi.org/10.3138/cjhs.252-A1

Skakoon-Sparling, S., Cramer, K. M., & Shuper, P. A. (2016). The Impact of Sexual Arousal on Sexual Risk-Taking and Decision-Making in Men and Women. *Archives of Sexual Behavior*, *45*(1), 33–42. https://doi.org/10.1007/s10508-015-0589-y

Spielberger, C. D. (1983). *State-trait anxiety inventory for adults.*

Stoléru, S., Grégoire, M. C., Gérard, D., Decety, J [J.], Lafarge, E., Cinotti, L., Lavenne, F., Le Bars, D., Vernet-Maury, E., Rada, H., Collet, C., Mazoyer, B., Forest, M. G., Magnin, F., Spira, A., & Comar, D. (1999). Neuroanatomical correlates of visually evoked sexual arousal in human males. *Archives of Sexual Behavior*, *28*(1), 1–21. https://doi.org/10.1023/a:1018733420467

Synofzik, M., Vosgerau, G., & Voss, M. (2013). The experience of agency: An interplay between prediction and postdiction. *Frontiers in Psychology*, *4*, 127. https://doi.org/10.3389/fpsyg.2013.00127

Takahata, K., Takahashi, H., Maeda, T., Umeda, S., Suhara, T., Mimura, M., & Kato, M. (2012). It's not my fault: Postdictive modulation of intentional binding by monetary gains and losses. *PloS One*, *7*(12), e53421. https://doi.org/10.1371/journal.pone.0053421

Tanaka, T., & Kawabata, H [H.] (2019). The Intentional Binding of Auditory and Visual Action Effects. *I-Perception*, *10*, 148.

Tanaka, T., Matsumoto, T., Hayashi, S., Takagi, S., & Kawabata, H [Hideaki] (2019). What Makes Action and Outcome Temporally Close to Each Other: A Systematic Review and Meta-Analysis of Temporal Binding. *Timing & Time Perception*, *7*(3), 189–218. https://doi.org/10.1163/22134468-20191150

Telch, M. J., Silverman, A., & Schmidt, N. B. (1996). Effects of anxiety sensitivity and perceived control on emotional responding to caffeine challenge. *Journal of Anxiety Disorders*, *10*(1), 21–35. https://doi.org/10.1016/0887-6185(95)00032-1

Tomer, R., Slagter, H. A., Christian, B. T., Fox, A. S., King, C. R., Murali, D., Gluck, M. A., & Davidson, R. J. (2014). Love to win or hate to Lose? Asymmetry of dopamine D2 receptor binding predicts sensitivity to reward versus punishment. *Journal of Cognitive Neuroscience*, *26*(5), 1039–1048. https://doi.org/10.1162/jocn_a_00544

Tracy, J. L., Cheng, J. T., Martens, J. P., & Robins, R. W. (2011). The affective core of narcissism: Inflated by pride, deflated by shame. In W. K. Campbell & J. D. Miller (Eds.), *Handbook of narcissism and narcissistic personality disorder: Theoretical approaches, empirical findings, and treatments.* (pp. 330–343). Wiley.

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*(1), 97–136. https://doi.org/10.1016/0010-0285(80)90005-5

Triller, C. (2003). *Faktorenstruktur des NPI-R: (revidierte deutsche Fassung des Narcissistic Personality Inventory, Raskin&Hall)Eine Studie zur Konstruktvalidität* [Dissertation]. Rheinisch-Westfälischen Technischen Hochschule Aachen, Aachen.

Ulloa, J. L., Vastano, R., George, N., & Brass, M. (2019). The impact of eye contact on the sense of agency. *Consciousness and Cognition*, *74*, 102794. https://doi.org/10.1016/j.concog.2019.102794

Ungless, M. A., Whistler, J. L., Malenka, R. C., & Bonci, A. (2001). Single cocaine exposure in vivo induces long-term potentiation in dopamine neurons. *Nature*, *411*(6837), 583–587. https://doi.org/10.1038/35079077

Urban, N. B. L., Slifstein, M., Thompson, J. L., Xu, X., Girgis, R. R., Raheja, S., Haney, M., & Abi-Dargham, A. (2012). Dopamine release in chronic cannabis users: A 11craclopride positron emission tomography study. *Biological Psychiatry*, *71*(8), 677–683. https://doi.org/10.1016/j.biopsych.2011.12.018

van der Westhuizen, D., Moore, J [James], Solms, M., & van Honk, J. (2017). Testosterone facilitates the sense of agency. *Consciousness and Cognition*, *56*, 58–67. https://doi.org/10.1016/j.concog.2017.10.005

van Gelder, J.-L. (2013). Beyond Rational Choice: the Hot/Cool Perspective of Criminal Decision Making. *Psychology, Crime & Law*, *19*(9), 745–763. https://doi.org/10.1080/1068316X.2012.660153

Vanderschuren, L. J. M. J., Schmidt, E. D., Vries, T. J. de, van Moorsel, C. A. P., Tilders, F. J., & Schoffelmeer, A. N. M. (1999). A Single Exposure to Amphetamine Is Sufficient to Induce Long-Term Behavioral, Neuroendocrine, and Neurochemical Sensitization in Rats. *The Journal of Neuroscience*, *19*(21), 9579–9586. https://doi.org/10.1523/JNEUROSCI.19-21-09579.1999

Vernon, P. A. (1993). Der Zahlen-Verbindungs-Test and other trail-making correlates of general intelligence. *Personality and Individual Differences*, *14*(1), 35–40. https://doi.org/10.1016/0191-8869(93)90172-Y

Volkow, N. D., Ding, Y. S., Fowler, J. S., Wang, G. J., Logan, J., Gatley, S. J., …, & Gur, R. (1996). Dopamine transporters decrease with age. *Journal of Nuclear Medicine,*, *37*(4), 554–559.

Volkow, N. D., Fowler, J. S., Wolf, A. P., Schlyer, D., Shiue, C. Y., Alpert, R., & Henn, F. (1990). Effects of chronic cocaine abuse on postsynaptic dopamine receptors. *Annual Review of Addictions Research and Treatment*(2(C)), 97–104.

Volkow, N. D., Gur, R. C., Wang, G. J., Fowler, J. S., Moberg, P. J., Ding, Y. S., Hitzemann, R., Smith, G., & Logan, J. (1998). Association between decline in brain dopamine activity with age and cognitive and motor impairment in healthy individuals. *The American Journal of Psychiatry*, *155*(3), 344–349. https://doi.org/10.1176/ajp.155.3.344

Volkow, N. D., Wang, G.-J., Tomasi, D., & Baler, R. D. (2013). Unbalanced neuronal circuits in addiction. *Current Opinion in Neurobiology*, *23*(4), 639–648. https://doi.org/10.1016/j.conb.2013.01.002

Voss, M., Moore, J [J.], Hauser, M., Gallinat, J., Heinz, A., & Haggard, P [P.] (2010). Altered awareness of action in schizophrenia: A specific deficit in predicting action consequences. *Brain : A Journal of Neurology*, *133*(10), 3104–3112. https://doi.org/10.1093/brain/awq152

Wang, C.-A., Baird, T., Huang, J., Coutinho, J. D., Brien, D. C., & Munoz, D. P. (2018). Arousal Effects on Pupil Size, Heart Rate, and Skin Conductance in an Emotional Face Task. *Frontiers in Neurology*, *9*, 1029. https://doi.org/10.3389/fneur.2018.01029

Ward, T., & Gannon, T. A. (2006). Rehabilitation, etiology, and self-regulation: The comprehensive good lives model of treatment for sexual offenders. *Aggression and Violent Behavior*, *11*(1), 77–94. https://doi.org/10.1016/j.avb.2005.06.001

Waszak, F., Cardoso-Leite, P., & Hughes, G. (2012). Action effect anticipation: Neurophysiological basis and functional consequences. *Neuroscience and Biobehavioral Reviews*, *36*(2), 943–959. https://doi.org/10.1016/j.neubiorev.2011.11.004

Watson, D. R., Garfinkel, S. N., van Gould Praag, C., Willmott, D., Wong, K., Meeten, F., & Critchley, H. D. (2019). Computerized Exposure Therapy for Spider Phobia: Effects of Cardiac Timing and Interoceptive Ability on Subjective and Behavioral Outcomes. *Psychosomatic Medicine*, *81*(1), 90–99. https://doi.org/10.1097/PSY.0000000000000646

Watson, P. J., & Morris, R. J. (1991). Narcissism, empathy and social desirability. *Personality and Individual Differences*, *12*(6), 575–579. https://doi.org/10.1016/0191-8869(91)90253-8

Wegner, D. M., & Wheatley, T. (1999). Apparent mental causation: Sources of the experience of will. *American Psychologist*, *54*(7), 480–492. https://doi.org/10.1037/0003-066X.54.7.480

Weiss, C., Herwig, A., & Schütz-Bosbach, S. (2011). The self in action effects: Selective attenuation of self-generated sounds. *Cognition*, *121*(2), 207–218. https://doi.org/10.1016/j.cognition.2011.06.011

Weller, L., Schwarz, K. A., Kunde, W., & Pfister, R. (2017). Was it me? - Filling the interval between action and effects increases agency but not sensory attenuation. *Biological Psychology*, *123*, 241–249. https://doi.org/10.1016/j.biopsycho.2016.12.015

Wen, W., Yamashita, A., & Asama, H. (2015). The influence of action-outcome delay and arousal on sense of agency and the intentional binding effect. *Consciousness and Cognition*, *36*, 87–95. https://doi.org/10.1016/j.concog.2015.06.004

Wilcox, C. E., Pommy, J. M., & Adinoff, B. (2016). Neural Circuitry of Impaired Emotion Regulation in Substance Use Disorders. *The American Journal of Psychiatry*, *173*(4), 344–361. https://doi.org/10.1176/appi.ajp.2015.15060710

Wills, T. A., & Stoolmiller, M. (2002). The role of self-control in early escalation of substance use: A time-varying analysis. *Journal of Consulting and Clinical Psychology*, *70*(4), 986–997. https://doi.org/10.1037/0022-006X.70.4.986

Wink, P. (1991). Two faces of narcissism. *Journal of Personality and Social Psychology*, *61*(4), 590–597. https://doi.org/10.1037/0022-3514.61.4.590

Winn, M. B., Wendt, D., Koelewijn, T., & Kuchinsky, S. E. (2018). Best Practices and Advice for Using Pupillometry to Measure Listening Effort: An Introduction for Those Who Want to Get Started. *Trends in Hearing*, *22*, 2331216518800869. https://doi.org/10.1177/2331216518800869

Wittmann, B. C., Schott, B. H., Guderian, S., Frey, J. U., Heinze, H.-J., & Düzel, E. (2005). Reward-related FMRI activation of dopaminergic midbrain is associated with enhanced hippocampus-dependent long-term memory formation. *Neuron*, *45*(3), 459–467. https://doi.org/10.1016/j.neuron.2005.01.010

Wolchik, S. A., Beggs, V. E., Wincze, J. P., Sakheim, D. K [David K.], Barlow, D. H [David H.], & Mavissakalian, M. (1980). The effect of emotional arousal on subsequent sexual arousal in men. *Journal of Abnormal Psychology*, *89*(4), 595–598. https://doi.org/10.1037/0021-843X.89.4.595

Wolpe, N., Haggard, P [Patrick], Siebner, H. R., & Rowe, J. B. (2013). Cue integration and the perception of action in intentional binding. *Experimental Brain Research*, *229*(3), 467–474. https://doi.org/10.1007/s00221-013-3419-2

Wolpe, N., & Rowe, J. B. (2014). Beyond the "urge to move": Objective measures for the study of agency in the post-Libet era. *Frontiers in Human Neuroscience*, *8*, 450. https://doi.org/10.3389/fnhum.2014.00450

Wolpert, D. M [D. M.], & Ghahramani, Z. (2000). Computational principles of movement neuroscience. *Nature Neuroscience*, *3 Suppl*, 1212–1217. https://doi.org/10.1038/81497

Wright, A. G. C., Pincus, A. L., Thomas, K. M., Hopwood, C. J., Markon, K. E., & Krueger, R. F. (2013). Conceptions of narcissism and the DSM-5 pathological personality traits. *Assessment*, *20*(3), 339–352. https://doi.org/10.1177/1073191113486692

Wu, T., & Barnes, J. C. (2013). Two dopamine receptor genes (DRD2 and DRD4) predict psychopathic personality traits in a sample of American adults. *Journal of Criminal Justice*, *41*(3), 188–195. https://doi.org/10.1016/j.jcrimjus.2013.02.001

Yang, H., Yang, S., & Isen, A. M [Alice M.] (2013). Positive affect improves working memory: Implications for controlled cognitive processing. *Cognition & Emotion*, *27*(3), 474–482. https://doi.org/10.1080/02699931.2012.713325

Yoon, J., & Knight, R. A [Raymond A.] (2015). Emotional processing of individuals high in psychopathic traits. *Australian Journal of Psychology*, *67*(1), 29–37. https://doi.org/10.1111/ajpy.12063

Yoshie, M [Michiko], & Haggard, P [Patrick] (2013). Negative emotional outcomes attenuate sense of agency over voluntary actions. *Current Biology : CB*, *23*(20), 2028–2032. https://doi.org/10.1016/j.cub.2013.08.034

Zeigler-Hill, V., Clark, C. B., & Pickard, J. D. (2008). Narcissistic subtypes and contingent self-esteem: Do all narcissists base their self-esteem on the same domains? *Journal of Personality*, *76*(4), 753–774. https://doi.org/10.1111/j.1467-6494.2008.00503.x

Zeigler-Hill, V., Fulton, J. J., & McLemore, C. (2011). The role of unstable self-esteem in the appraisal of romantic relationships. *Personality and Individual Differences*, *51*(1), 51–56. https://doi.org/10.1016/j.paid.2011.03.009

Zekveld, A. A., Koelewijn, T., & Kramer, S. E. (2018). The Pupil Dilation Response to Auditory Stimuli: Current State of Knowledge. *Trends in Hearing*, *22*, 2331216518777174. https://doi.org/10.1177/2331216518777174

Zhang, H., Wang, Z., You, X., Lü, W., & Luo, Y. (2015). Associations between narcissism and emotion regulation difficulties: Respiratory sinus arrhythmia reactivity as a moderator. *Biological Psychology*, *110*, 1–11. https://doi.org/10.1016/j.biopsycho.2015.06.014

Zuckerman, M. (2010). Sensation Seeking. In I. B. Weiner & W. E. Craighead (Eds.), *The Corsini Encyclopedia of Psychology*. John Wiley & Sons, Inc. https://doi.org/10.1002/9780470479216.corpsy0843

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