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Journal of Cognition and Neuroethics

What Neuroimaging of the Psychedelic State Tells Us about the Mind-Body Problem

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Biography

Bernardo Kastrup has a Ph.D. in computer engineering with specializations in artificial intelligence and reconfigurable computing. He has worked as a scientist in some of the world's foremost research laboratories, including the European Organization for Nuclear Research (CERN) and the Philips Research Laboratories (where the "Casimir Effect" of Quantum Field Theory was discovered). Bernardo has authored many scientific papers and philosophy books. His three most recent books are: More Than Allegory, Brief Peeks Beyond and Why Materialism Is Baloney.

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What Neuroimaging of the Psychedelic State Tells Us about the Mind-Body Problem

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Abstract

Recent neuroimaging studies of the psychedelic state, which have commanded great media attention, are reviewed. They show that psychedelic trances are consistently accompanied by broad reductions in brain activity, despite their experiential richness. This result is at least counterintuitive from the perspective of mainstream physicalism, according to which subjective experience is entirely constituted by brain activity. In this brief analysis, the generic implications of physicalism regarding the relationship between the richness of experience and brain activity levels are rigorously examined from an informational perspective, and then made explicit and unambiguous. These implications are then found to be non-trivial to reconcile with the results of said neuroimaging studies, which highlights the significance of such studies for the mind-body problem and philosophy of mind in general.

Keywords

Neuroimaging, Psychedelics, Mind-Body Problem, Consciousness, Neural Correlates of Consciousness, Physicalism, Metaphysics

Introduction

Recently, two remarkable neuroimaging studies of the neural correlates of the psychedelic state have been completed: the first investigated the effects of psilocybin, the main psychoactive compound in magic mushrooms (Carhart-Harris et al 2012), while the second focused on lysergic acid diethylamide, or LSD (Carhart-Harris et al 2016). The first study has shown that, despite the significantly higher richness of experience reported by subjects on psilocybin when compared to those on placebo, measurements of Cerebral Blood Flow (CBF) with functional magnetic resonance imaging (fMRI) indicated that psilocybin caused *only reductions* of neural activity. No increases in CBF were seen anywhere in the brain. In the second study, localized increases in CBF were observed in the visual cortex of subjects on LSD, but magnetoencephalography (MEG)—which performs a more direct measurement of neural activity than CBF—again revealed reductions in activity throughout the brain. The slight discrepancy in CBF measurements between the two studies was explained by the researchers in the following manner: 'One must be cautious of proxy measures of neural activity (that lack temporal resolution),

such as CBF … lest the relationship between these measures, and the underlying neural activity they are assumed to index, be confounded by extraneous factors, such as a direct vascular action of the drug' (Carhart-Harris et al 2016, 5). They proceeded to say that 'more direct measures of neural activity (e.g., EEG and MEG) … should be considered more reliable indices of the functional brain effects of psychedelics' (Carhart-Harris et al 2016, 6).

The results of both studies thus indicate that the psychedelic state is consistently associated with *reductions* of brain activity, despite the significant *increases* in the richness of experience reported by subjects. From the point of view of the metaphysics of physicalism, which entails that experience is constituted by brain activity alone, such results are at least counterintuitive. Indeed, neuroscientist Christof Koch commented that, '*to the great surprise of many*, psilocybin, a potent psychedelic, reduces brain activity' (Koch 2012, my italics). But does this observation strictly contradict physicalism? Does physicalism imply that an increase in the richness of experience must be accompanied by an increase in brain activity?

In this brief analysis, the implications of physicalism regarding the relationship between subjective experience and brain activity will be rigorously examined from an informational perspective. The goal is to establish whether the results reported in the neuroimaging studies cited above can be reconciled with physicalism and, if so, under what circumstances. Indeed, as neuroimaging advances and its applications begin to touch on difficult and nuanced problems in neuroscience and philosophy of mind, it becomes crucially important that the related implications of physicalism be unambiguously understood. This is what is attempted here. As such, although this brief analysis focuses only on the psychedelic studies cited, its relevance potentially extends to many more areas of neuroscientific investigation.

The Implications of Physicalism

Physicalism posits that there are physical entities independent of experience and that the qualities of experience are constituted by particular arrangements of such entities. More specifically, under physicalism the qualities of experience are constituted by particular patterns of brain activity, which are called the 'Neural Correlates of Consciousness' (NCCs). Notice that I use the word 'activity' here in the broad and generic sense of metabolism itself, so that only a dead, non-metabolizing brain has no activity.

Not all brain activity consists of NCCs: under physicalism, there are also unconscious neural processes. Reductions in these unconscious processes don't necessarily imply

reductions in experience, for they aren't NCCs. In fact, if these unconscious processes are inhibitory in nature, their reduction could even cause an increase in NCCs and, therefore, experience. As such, nothing precludes an increase in NCCs from being accompanied by a comparatively greater decrease in unconscious processes, leading to an overall decrease in brain activity. Clearly then, physicalism does *not* necessarily imply that more experience should always correlate with more *total* brain activity.

But here is the critical point: under physicalism, an increase in the richness of experience *does* need to be accompanied by an increase in the metabolism associated *with the NCCs*, for experiences are supposedly constituted by the NCCs. Let us unpack this carefully.

Rich experiences span a broader information space in awareness than comparatively dull and monotonic experiences. This is fairly easy to see: the experience of seeing a colorful fireworks display entails more information in awareness than staring at an overcast night sky. Listening to Bach's Brandenburg Concertos entails more information in awareness than sitting in a relatively silent room. Having an intense dream entails more information in awareness than deep sleep. And so on. There clearly are such things as *richer* and *duller* experiences.

The concept of information is crucial here: it is a measure of how many different states can be discerned in a system. *More* information means that the system comprises *more* states that can be discerned from each other (Shannon, 1948). In the case of human experience, information reflects the amount of subjectively apprehended qualities that can be discerned from each other in awareness. Watching a fireworks display entails more information than staring at a dark sky because one can discern more shapes, colors, movements and levels of brightness in the former case. Listening to the Brandenburg Concertos entails more information than sitting in a relatively silent room because one can discern more tones, rhythms, timbres and levels of volume in the former case. To say that an experience is richer thus means that the experience entails *more information* in awareness.

Information states can be discerned in time (such as the progressive unfolding of notes in a symphony) and space (such as the different shapes and colors within a single snapshot of a fireworks display). In practice, however, a single moment is experientially intangible. The bulk of the information within awareness is associated with how many, and how often, qualities *change* over time. Therefore, when we speak of richer experiences we essentially mean experiences wherein a higher number of discernible qualities change more frequently.

Now, since physicalism entails that there is nothing to the qualities of experience but the states of its physical substrate, an increase in the richness of experience can only be explained by more, and/or more frequent, state changes in the parts of the brain corresponding to the associated NCCs. We call these physiological state changes *metabolism*, or *neural activity*. Therefore, a relative increase in *local* metabolism is necessary to create the broader information space in the brain that supposedly constitutes the broader information space in awareness entailed by richer experiences. This is an inescapable implication of physicalism. Without it, subjective experience would become decoupled from the workings of the living brain information-wise. Operationally, thus, physicalism implies a form of *local* proportionality: the richness of experience must be proportional to the compound metabolic level *of the NCCs*, even though it doesn't need to be proportional to the *total* level of activity in the brain.

An analogy may be helpful at this point. If we model the brain as a cellular automaton (e.g. Gers, Garis, & Korkin 2005), metabolism is a measure of how many, and how often, cells change states as time goes by (a 'cell' in a cellular automaton doesn't necessarily correspond to a neuron, mind you). A brain displaying high activity corresponds to an automaton wherein many cells change states frequently. A brain displaying low activity corresponds to an automaton wherein a few cells change states now and then. The conclusion from the discussion above can thus be restated as follows: richer experiences, under physicalism, must correlate with an increase in the number of cells encompassed by the NCCs, and/or more frequent state changes in said cells.

Notice that this is a generic conclusion derived from first-principles informational considerations. It is independent of the exact nature of the NCCs. Neural spiking, neurotransmitter releases, fluctuations of membrane potentials, network configurations, communication or information integration patterns across neurons, etc.: whatever the NCCs turn out to be or encompass, it remains a direct implication of physicalism that *an increase in the richness of experience needs to be accompanied by an increase in the compound level of metabolism associated with the NCCs.*

Interpreting the Neuroimaging of the Psychedelic State

Given the previous section's conclusion, what does it mean for the plausibility of physicalism that psychedelic trances are *not* accompanied by increases in brain activity? The first thing to consider is that psychedelic trances entail a significant increase in the richness of experience when compared to an ordinary baseline. This is not only overwhelmingly attested by informal reports (such as those available online

at, for instance, the 'Erowid Experience Vaults'), it has also been confirmed in controlled studies. In the first study cited above, subjects on psilocybin reported extremely vivid imagination, dream-like experiences and complex perceptual hallucinations (Carhart-Harris et al 2012, 2138-2139), which characterized the psychedelic state unambiguously as experientially richer—i.e. spanning a broader information space in awareness—than the placebo state. In an earlier study, subjects characterized the psychedelic state as extremely rich, intense and even 'more real than real' (Strassman 2001). In yet another study, 67% of the subjects rated a psychedelic experience as among the top five most spiritually significant of their life, considering 'the meaningfulness of the experience to be similar, for example, to the birth of a first child or death of a parent' (Griffiths et al 2006, 276-277). It is difficult to imagine how this could fail to imply that a psychedelic experience is richer than most other experiences in life. Thus, under physicalism, one would have expected the psychedelic neuroimaging studies cited above to have shown unambiguous local increases in brain activity corresponding to the NCCs. How can we reconcile physicalism with the fact that this was *not* the case? There are two hypotheses.

The first hypothesis is that the spatial resolution of fMRI may have been too coarse for researchers to discern between (a) hypothetical NCCs whose activity did increase and (b) unconscious processes right 'on top of' said hypothetical NCCs, whose metabolic drop masked the activity rise of the NCCs. But this possibility stretches plausibility, for it entails the rather unlikely coincidence that each and every NCC was consistently accompanied by an unconscious process intermingled with it, whose metabolism happened to decrease so significantly as to mask the corresponding NCC increase. There is no reason why these different neural processes should unfold in such a perfect spatio-temporal intermingling. Indeed, different neural processes are normally discernible from each other in neuroimaging, otherwise neuroimaging wouldn't be of much use in the first place.

The second hypothesis is that all the information entailed by the psychedelic experience—and, therefore, the corresponding level of metabolism—is *already* in the baseline brain activity of the subjects. Prior to drug intake, the information is simply not in the NCCs. In other words, the 'trip' may unfold in the brain at all times, in the form of unconscious processes. The psychedelic compound may simply convert those *existing* unconscious processes into NCCs, which then brings the trip into awareness. What this conversion may entail and how it may happen remains completely unclear and highly speculative, but the hypothesis could, at least in principle, explain why no activations were observed with respect to the placebo baseline: subjects who received placebo may have also been 'tripping' subliminally, displaying all the corresponding metabolism.

There are two problems with this second hypothesis. The first is that it implies that the brain of every person is busy physically computing a 'trip' *all the time*, below the threshold of awareness. To put this in context, notice that psychedelic 'trips' often include voyages to indescribable parallel realms; death- and birth-like experiences; conversations with what is often described as alien entities or deities; unfathomable and countless insights into the underlying nature of reality and self; the witnessing of indescribably complex structures and motion; synesthetic traversals of the entire gamut of human emotions and beyond; etc. (Strassman 2001 & Strassman et al 2008). It is at least difficult to conceive of a reason why evolution would have led to brains that systematically wasted energy and considerable cognitive resources to continuously maintain useless subliminal 'tripping.' To put it in perspective, consider for instance what can be accomplished in art or engineering with the cognitive resources associated with imagining a single complex structure in movement. Many of us have difficulties with simple 3D perspective, let alone the movements of complex structures. Yet, the hypothesis here implies that we are all subliminally wasting many more resources than this *all the time*. Such an idea seems, again, to stretch plausibility.

The second problem with the second hypothesis is this: in another brain imaging study, researchers used fMRI to measure the neural activity of subjects as they slept and dreamed (Horikawa et al 2013). The metabolic activity corresponding to dreaming up trivial visual experiences, such as seeing a person take a photograph or staring at a bronze statue (Costandi 2013), was clearly identifiable. So the added metabolism of dreaming up trivial images is significant enough to be picked out from the baseline activity wherein, *ex hypothesi,* unfathomable psychedelic 'tripping' is continuously taking place. This suggests that the metabolic level of the hypothetical subliminal 'trip' *cannot* be overwhelmingly higher than that of the trivial dream. If it were, the activity signal of the dream would have been mere noise, indiscernible from the baseline. Yet, in terms of information richness, the experience of e.g. staring at a bronze statue is negligible in comparison to that of a full-blown psychedelic trance. Therefore, given the previous section's conclusion, the trivial dreams should have been metabolically negligible and indiscernible from the baseline, which reduces the second hypothesis to a contradiction.

In conclusion, both hypotheses conceived to reconcile physicalism with the results of recent neuroimaging studies of the psychedelic state are implausible. At present, it remains unclear if and how physicalism can accommodate such neuroimaging results. This, of course, does not mean that the results outright refute physicalism in and of themselves. Other hypotheses may exist that have not been considered in this brief analysis and further studies of the neural correlates of the psychedelic state may reframe

the current results. Until more clarity is achieved, however, one is left with this sobering thought: dreams and psychedelic trances are analogous in that neither can be attributed to sensory inputs, both being entirely imagined experiences. Yet, in a dream, when one experiences something as dull as staring at a bronze statue, the corresponding brain activations can be clearly discerned by fMRI. But when one undergoes psychedelic trances rated by 67% of subjects as one of the five most significant experiences of their lives, *no conclusive activations can be discerned anywhere in the brain*.

Conclusions

The generic implications of the physicalist metaphysics regarding the relationship between the richness of experience and brain activity levels have been rigorously examined and made explicit and unambiguous. The examination was done from the perspective of informational first principles. Recent neuroimaging studies of the psychedelic state have also been reviewed and their results found to be non-trivial to reconcile with said generic implications of physicalism. This suggests that either (a) future research into the neural correlates of the psychedelic state will reframe the present results in a manner more amenable to physicalist interpretations; (b) new interpretative hypotheses will emerge to accommodate the present results under plausible physicalist scenarios; or (c) neuroimaging studies of the psychedelic state will render physicalism untenable as a metaphysical option for resolving the mind-body problem.

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Does Drug Addiction Prove Free Will?

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Does Drug Addiction Prove Free Will?

Alex Lench

Abstract
In this article I discuss two premises, firstly, that drug addiction is characterised by impaired control over drug taking and secondly, that free will is the capacity for choice. I shall then discuss the subsequent implication of these two premises, that the existence of the disease of drug addiction is empirical evidence for free will. Finally, I consider how this view may fit with other neuroscientific findings of free will and the moral implications of this argument. Whilst the relationship between drug addiction and free will has previously been discussed in various ways, this essay is specifically concerned with highlighting areas of overlap between philosophical and ethical considerations of compatibilism and the science of addiction.

Keywords
Free Will, Drug Addiction, Compatibilism

Drug Addiction as Loss of Control

Modern diagnostic criteria for addiction see continued use despite negative consequences and impaired control over drug taking as the fundamental elements of addiction (American Psychiatric Association 2013). The characterisation of addiction in psychiatry by compulsive or uncontrolled drug seeking was not, however, conceded lightly. The earliest characterisations viewed drug addiction as a social problem and the condition was designated as a personality disorder (see Saunders 2006). Later, biological elements of addiction were acknowledged but addiction was described by the presence of physical withdrawal syndromes which lead to dependent users re-taking drugs in order to negate their symptoms. Whilst such a view was desirable in that it preserved voluntary behaviour it failed to effectively characterize drug addiction, particularly in accounting for drugs which are highly addictive without producing withdrawal symptoms (see Hyman 2007).

In 1987 with the revision of the DSM III, psychiatry conceded the vulnerability of our capacity for self-control and that characterising addiction as uncontrolled drug-seeking behaviour was necessary for accurate diagnosis of this disease. This view has remained though the term 'dependence' was used for addiction until the publication of the DSM V, owing to concerns over the possibly pejorative nature of this term (O'Brien 2011). David Nutt gives the psychiatric stance on addiction bluntly: *"Anyone who's met an addict*

knows that most addicts don't want to take drugs, but they're compelled to by something that is beyond them" (Boyce 2013). In asserting this finding the science of addiction became one with moral implications and the critique of science in this area can act as a proxy for debates of moral responsibility. An important argument against this scientific view of addiction is that it endorses the submission of addicts towards drug taking and may therefore dissuade them from confronting their disease. However, whilst this view asserts that control over drug-taking can be impaired, it also acknowledges that control can be recovered, through detoxification, treatment and external prostheses (Hyman 2007).

Free Will as the Capacity for Choice

Above the quantum level at least, all physical effects are adequately determined i.e. they are caused, not random, and all events thereby form part of an unbreakable and inevitable causal chain. The view of compatibilism is often most associated with the enlightenment thinker David Hume and its modern day champion Daniel Dennett. Compatibilism is the view that free will is compatible with this determinism and sees the 'causal chain' as constituting our freely made deliberations and decisions. The main objection to the compatibilist view is that if our behaviour is determined then it can only ever occur in one way and in this sense we are not 'free' to act otherwise. The difference here is in thinking that as the decision was caused it was in some way compelled, but the compatibilist view asserts that the scientific laws of free will are descriptive of, not prescriptive to, our free will (Berofsky 2002).

In the compatibilist view then the will is free in that we are able to make wilful decisions over how to act, it is the capacity for choice. In this way it has often been argued that compatibilism functions by defining a bland variety of free will and such a criticism was perhaps most notably stated by Kant (1909). However, the compatibilists typically counter such criticism by stating that it is the defining of free will as something which could exist only as a metaphysical construct that leads to confusion or the "pseudo-problem" of free will, as Moritz Schlick described it (Schlick 1962).

The other major affirmative position of free will is libertarianism which asserts indeterminism, often as part of a mind-body dualism, as a requirement for free will. The major philosophical objection to this view is that if our decisions are influenced by randomness, then in what sense can we lay claim to them and in what sense are they truly decisions? Indeterminism also presents the scientific problem of reconciling indeterminacy with the function of the brain. This problem was notably confronted by

the neurophysiologist John Eccles, though more recently the biologist Martin Heisenberg has looked to single cell life in an examination of this issue (Heisenberg 2009).

Heisenberg like some other libertarians such as Bob Kane, argues for a combination of indetermined and determined elements in free will thereby theoretically achieving both freedom from the causal chain and wilfully determined actions. The philosopher Alfred Mele has indicated that we can remain 'agnostic' on the exact details of free will as both compatibilism and libertarianism argue for free will as autonomism and thus we can accept autonomism without final knowledge of which view is true. However, in synthesising a form of libertarianism to reach his standard of autonomism Mele again indicates the necessity of a compatibilist decision making stage (Mele 1995). Such ideas emphasise the compatibilist thesis of free will being the capacity to choose our actions i.e. for control, and this necessitates causality (Mele 1995). However, whether we assert compatibilism in its entirety or remain agnostic on whether indeterminism may influence our thoughts prior to our decision is not crucial here. A simple expression of this notion of free will can be found in Hobart (1934): *"Two courses of action present themselves to my mind. I think of their consequences, I look on this picture and on that, one of them commends itself more than the other, and I will an act that brings it about."*

Does Drug Addiction Prove Free Will?

Whilst completely dependent on its premises, the argument presented here can now be stated: If we have the capacity to become impaired in our ability for choice over whether or not to take a rewarding drug, then clearly in the first place we do have the ability to make such a choice and so we do have free will. When we become addicted we lose (at least to an extent) the ability to wilfully decide for or against taking the drug in the normal way – as described by Hobart. In the compatibilist view we lose free will, with respect to taking the drug at least, and evidence for the capacity to lose a quality betrays its existence. This is the central contention of this essay, that evidence for drug addiction as being the loss of control over drug taking is empirical evidence for the existence of free will.

Profound insights into free-will were produced by the experiments of Benjamin Libet which demonstrated that, for some actions at least, brain activity precedes conscious perception of the decision to act (Libet et al. 1979). Some have taken such experiments to indicate that consciousness is purely along for the ride and we are self-deceived by an illusion of conscious control (Wegner 2003). Such epiphenomenalist conclusions leave us in a somewhat confusing position, not least because of the difficulty in seeing why such

a system would evolve (Popper and Eccles 1977). Michael Gazzaniga suggests that such ideas are flawed due to crude thinking on (or the language of) causality and advocates a view of consciousness as an emergent layer of organisation with its own timescale. In this view our consciousness may both cause and be constituted by brain activity analogous to the way that a computer program causes and is constituted by the microscopic physics of hardware (see Gazzaniga 2011).

The loss of control in addiction is thought to be due to a dysfunction in top-down signalling from the prefrontal cortex which results in a reduced inhibition over drug-responses (Jentsch and Taylor 1999). Brain imaging studies have observed that addicts have decreased activity in several prefrontal regions (Volkow et al 2012) and patients with prefrontal cortex damage exhibit similar deficits in decision making (Becara 2005). This is consistent with the long-standing view of the prefrontal cortex as being the central area for our cognitive control. This encompasses a range of 'executive' functions including working memory, retrieval and selection of information, value representation and inhibitory control which ultimately allow us to orchestrate our thoughts and make decisions (Miller and Cohen 2001, Funahashi and Andreau 2013). Whichever view is taken on the implications of the findings of Libet, the compatibilist thesis of free will is affected only in the nature of how consciousness is involved. However, the argument presented here indicates that free will can be characterised by that which is impaired in the addictive state, and this is our cognitive control.

Moral Relevance

As the basic argument by Galen Strawson (1994) illustrates, compatibilism does not see that we are 'ultimately' responsible for the factors determining our decisions, our *"motives, inclinations and circumstances"* as Hume (1777) described them, and this may alter our perspective on the idea of retributive justice. However, what is central to utilitarian justice is that we are able to choose whether or not to act according to the mutual laws of our society – it is our free will. Therefore our capacity to lose control is crucially important in that it affirms our moral competence, as noted by Daniel Dennett: *"We are rightly concerned to maintain our integrity as choosers so that we can be responsible for the actions our bodies engage in"* (Dennett 2012). Further to this however, there is psychological evidence that the very belief in free will itself can affect moral attitudes (Vohs and Schooler 2008), highlighting the importance of extended consideration on these issues.

The argument presented here also has strong implications for animal ethics and ideas of human exceptionalism. The raw compatibilist view asserts that all animals have free will and many animals appear to have the capacity for addiction, supporting this idea. However, no other animal, and particularly non-primates, have a well-developed pre-frontal cortex. Also, as discussed, compatibilist free will is closely tied to moral responsibility but the idea of holding animals to be morally accountable for their behaviour would appear quite absurd. Within compatibilism, many philosophers have confronted such problems and have described different types or elements of free will and future examination of these may be useful. For example, Mortimer Adler described an 'acquired freedom of self-perfection' as the ability to make decisions based on reasons over a slavery to passions (Adler 1958). It is interesting to consider whether such an idea may serve as a more accurate description of free will as implied by the human capacity for addiction and to what extent such a term may be synonymous with neuroscientific formulations such as cognitive control.

Conclusion

In the compatibilist view we are freely able to choose our actions in a determined universe. Science indicates that drug addiction is inescapably characterised by a loss of control and this reciprocally supports this compatibilist notion of free will. Whilst the experiments of Libet have raised questions over the role of our consciousness, this argument indicates that our free will may be better identified with prefrontal executive functions. As evidence for compatibilist free will, the existence of drug addiction affirms the moral competence of human beings though raises questions for animal ethics.

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Journal of Cognition and Neuroethics

Neuro-Societies? Attitudes and Perceptions in a German Public towards the Neurosciences

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Neuro-Societies? Attitudes and Perceptions in a German Public towards the Neurosciences

Anna-Lena Lumma and Saskia K. Nagel

Abstract

Findings from the neurosciences are increasingly discussed publicly. In neuroethical debates it is often assumed that the general public perceives neuroscientific topics as highly relevant and that it is influenced by the neuroscientific narratives that pervade the public sphere. However, studies on the actual uptake of neuroscientific research particularly with a focus on neuroplasticity in the wider public are scarce. Here, we investigate how a wider public perceives the neurosciences with an explorative survey in order to assess how the wider public's everyday life is influenced by the neurosciences. The questionnaire specifically targets the public's attitudes about the alterability of the brain. The explorative survey included 125 closed-ended and open-ended questions and was completed by participants from the German population. The findings showed that participants were very interested in the brain and its functions related to health, aging and learning, and thought about the influence of the neurosciences on topics relevant to their own life and society. The majority of participants did not know the concept of neuroplasticity, but nevertheless they believed that the brain can be altered. This study provides first insights into how neuroscientific information is perceived in the public and how the neurosciences impact people's everyday life.

Keywords

Neuro-ethics, Neurocultures, Public Attitudes, Neuroplasticity, Neuro-enhancement

Introduction

Since the 1990s, there has been an increasing public awareness on the progress of modern neuroscience (Racine et al. 2010, O'Connor, Rees, and Joffe 2012). Traditionally, the neurosciences examined basic research questions about the brain by invasively studying the nervous system of non-human animals or non-invasively investigating humans. Invasive studies in humans were rare, and restricted by manifold factors. However, advances in technology over the last three decades led to enormous improvements of empirical methods employed by the neurosciences. Particularly neuroimaging methods like fMRI and EEG made it possible to study the human brain in non-invasive ways and allowed new kinds of research questions to be asked and cross-disciplinary research to emerge. With the advancement of new scientific methods including e.g. EEG and fMRI it is now easier for the neurosciences to address fundamental questions about human nature that before were primarily investigated by the humanities.

Exemplary cross-disciplinary research topics that are studied by the neurosciences are cognition, emotions, development, ageing, personality traits, and the maintenance of health. Various academic fields like economy (Ariely and Berns 2010, Sanfey et al. 2003), education (Blakemore and Frith 2005, Goswami 2006), philosophy (Churchland 1989, Northoff 2004), ethics (Gazzaniga 2005, Farah 2005, Illes et al. 2010, Roskies 2002), law (Eagleman 2008, Goodenough and Tucker 2010), or art (Ramachandran and Hirstein 1999, Zeki and Nash 1999) now complement their own research by making use of neuroscientific methods. Consequently, the cross-disciplinary interest in the neurosciences lead to an emergence of neuro-hyphen disciplines or *neurocultures* (Frazzetto and Anker 2009) like neuro-economics, neuro-education, neuro-philosophy, neuro-ethics, neuro-law, neuro-theology, or neuro-aesthetics. The rise of these *neurocultures* within academia suggests that the neurosciences pervade academia in multiple ways. To better understand the roles that the neurosciences have in academia, investigations on whether the neurosciences have an authoritative role within academia, and how they specifically influence scientific conduct are necessary (Joyce 2005, Ortega and Vidal 2011, Choudhury et al. 2009, Rose and Abi-Rached 2013).

The focus of the current work is to investigate the role of the neurosciences outside the context of academia. With an increase of campaigns like the *Brain Awareness Week* initiated by the Dana Foundation and the emergence of a plethora of popular science books, education initiatives, and museum events the neurosciences reach out to a wider public. Furthermore, neuroscientific findings are increasingly covered in the public media, which can be regarded as major platform of information exchange between the sciences and the wider public (Illes et al. 2010, Robillard and Illes 2011, Racine et al. 2010, O'Connor, Rees, and Joffe 2012). In addition, the neurosciences found their way into domains of marketing and different branches of industry (Sylvan and Christodoulou 2010).

The public discourse and media coverage about the neurosciences raises new questions on how people engage with scientific knowledge, and how they might be influenced by the sciences, particularly the neurosciences. Among the questions that were raised in recent discussions about the public understanding of the neurosciences were the following: How much does the wider public trust in science and neuroscientific research specifically (Weisberg et al. 2008, Gauchat 2011, Resnik 2011, Gruber and Dickerson 2012)? What are the public attitudes toward cognitive and decisional enhancement (Fitz et al. 2014, Felsen, Castelo, and Reiner 2013, Schelle et al. 2014)? Do new technologies that are inspired by neuroscientific research change people's thinking, values, self-perception, and actions (Malabou 2009, O'Connor, Rees, and Joffe 2012, O'Connor and

Joffe 2013)? Do people perceive the neurosciences as risky, and might neuroscientific findings be used in order to promote interests of certain lobbies (Greely 2012, Caulfield, Rachul, and Zarzeczny 2010, Scott 2012, Yoon et al. 2012)? It has been suggested that an increase of neuroscientific knowledge might impact the law and lead to a redefinition of concepts like moral responsibility and free will (Greene and Cohen 2004). However, data from an empirical study by DeBrigard (De Brigard, Mandelbaum, and Ripley 2009) suggests that the attribution of moral responsibility does not change if actions can be explained by neurobiological concepts. In line with this study, O'Connor and Joffe (O'Connor and Joffe 2013) emphasize that the public discourse about the neurosciences does not lead to a change in commonplace concepts about self and society.

Those and similar questions are frequently discussed but often lack direct supporting evidence from the wider public. To better capture to what extent the neurosciences influence society, it is important to directly assess how the wider public perceives the neurosciences (Nadler and Reiner 2011). Here, we offer a contribution to integrate attitudes of a wider public in the discussion of societal implications of the neurosciences. Involving the public in this discourse is particularly important, because it could illuminate the interrelations between science communication and society (Felsen, Castelo, and Reiner 2013). Additionally, it furthers the understanding about how individual people and society at large are influenced by neuroscientific progress, and how certain values and practices e.g. in therapy but also in everyday life are changing (Farah 2005, Glannon 2007, Levy 2007, Kaposy 2009, Nagel 2010). Here, we present an explorative survey that addresses how a wider population perceives and evaluates neuroscientific research findings. Our study specifically investigates how people conceive of the possibility to alter the brain. This topic touches many aspects of everyday life such as the malleability or stability of personality traits, the manifold facets of development and education, the capacity of lifelong learning, ageing, and treatment of neurological diseases including rehabilitation. The results of this explorative study shed new light on how this research might influence the wider public's everyday life, and further on how the actual recipients of the media covering neuroscientific topics think about the neurosciences. The results might also indicate how the self-image of individuals is affected by the neurosciences and particularly by the insights about the alterability of the brain. The overall goal of the study is to provide insights about the feedback loops between science and society and enrich the discussion about the influences of the neurosciences on society.

Methods

Participants

A total of 364 respondents filled out the questionnaire. The sample included 208 female participant, 152 male participants, and 4 not stated. The participants' age ranged from 15 to 78 years (mean age = 37.9 years; standard deviation = 15.8), 11 not stated. The education backgrounds ranged from university degree (44.2%, n = 155), higher education entrance qualification (28.2%, n = 99), secondary school leaving certificate (13.1%, n = 46), a PhD (10.3%, n = 36), lower secondary school leaving certificate (4.0%, n = 14) to no school education (0.3%, n = 1), 13 not stated.

Design & Procedure

We designed an exploratory cross-sectional questionnaire survey to measure the public's[1] interests, beliefs, opinions, and attitudes about the neurosciences.

The questionnaire contained 125 questions in total, comprising 103 close-ended questions and 22 open-ended questions. Close-ended questions had varying answer options including 1) 'yes' and 'no', 2) 'very strong', 'strong', 'rather not', 'not at all', 3) 'very high', 'high', 'rather low', 'very low', 4) 'yes', 'rather yes', 'rather no', 'no', 5) 'daily', 'weekly', 'monthly', 'less than monthly', 6) 'very little', 'little', 'rather little', 'rather much', 'much' and 'very much', 7) 'extremely important', 'rather important', 'rather unimportant', 'extremely unimportant', 8) 'very strong', 'strong', 'rather not', 'not at all' and 9) 'very often', 'more often', 'rarely', 'very rare/never' . Some questions that measured the knowledge about certain topics included several knowledge options as answers and the option 'not known'. To investigate how the wider public perceives the neurosciences, the questionnaire covered topics such as participants' perception of neuroscientific information, participants' prior knowledge about the neurosciences, participants' belief of trustworthiness of the neurosciences, participants' knowledge and ideas about influences on the brain, enhancement, ageing, happiness, and the perceived influence of the neurosciences on societal topics. Participants either completed a paper version or an online version of the survey. The content of both versions did not differ from another in any relevant aspect. The online version was constructed using the MAQ program, a web based free questionnaire generator (www.maq-online.de). Paper versions

1. "The public, of course, is not a monolith, but rather a conglomeration of numerous "publics"" (Fitz et al. 2014). Our survey aimed at the general lay public without particular restrictions aiming for a broad mixture of (educational) backgrounds and ages.

of the questionnaire were distributed in public areas, workplaces, educational institutions, and public transportation. Online questionnaires were shared mainly over social and institutional network platforms and mailing lists. Participants were instructed that the survey is about their beliefs and opinions on the neurosciences. Participants were not given any information about what constitutes the neurosciences, because one goal of the study was to find out what they believe and know about the neurosciences. Participants were briefed about the purpose of the study and the protection of data privacy. This survey was set up as an exploratory study and results are reported in percentages from all available data.

Results

The 125 survey questions were grouped into four thematic areas covering 1) participants' interest and knowledge about the brain and the neurosciences, 2) participants' attitudes about the neurosciences, 3) participants' beliefs about the alterability of the brain and its capacities, and 4) participants' opinions about the relation between neuroscience and societal topics.

Area 1. Interest and knowledge about the brain and the neurosciences

Participants indicated an overall high interest in the brain (Figure 1). Topics that they were most interested in included brain function (12%), followed by memory (7.5%) and learning (5.6%). In addition, participants also mentioned several other topics of interest related to brain development, consciousness, concentration, enhancement, dreams, and psychosomatics. Participants reported to occasionally hear something about the brain in the media (Figure 2).

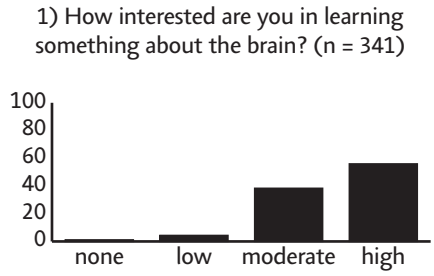

Fig. 1 Participants' ratings about their interest in learning something about the brain

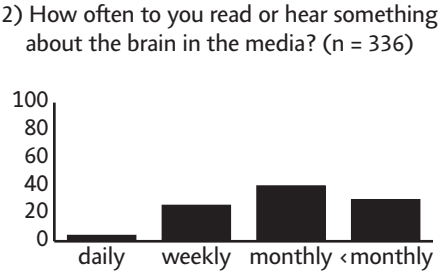

Fig. 2 Participants' responses about how often they hear something about the brain in the media

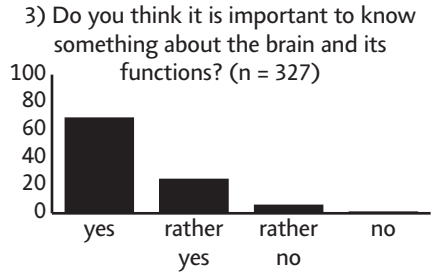

Fig. 3 Participants' opinion about whether they think it is important to know something about the brain

Notably, almost the whole sample agreed that it was important to "know something about the brain" (Figure 3). In an open question the participants provided reasons why they think it is important to "know something about the brain." The most frequent answers given were: "acquiring knowledge of health and treatment processes", "understanding cognitive functions" as well as "understanding human behaviour" and "human nature" in general.

To assess the respondents' knowledge about the neurosciences we asked 7 multiple-choice questions about neuroscientific facts (Figure 4). The majority of participants answered the questions correctly. However the majority of participants did not know what fMRI is (see Figure 4c).

Area 2. Attitudes towards the neurosciences

To understand what our participants think about the neurosciences we asked them the following questions about their attitudes regarding the neurosciences and their beliefs about the neurosciences' relevance and related risks:

1) How important do you find the neurosciences in comparison to other scientific disciplines?

2) Do you think that the neurosciences are better capable of investigating mental states than other scientific disciplines?

3) How significant are the neurosciences for your everyday life?

4) How much do you trust scientific findings?

5) How high do you estimate the potential of the neurosciences for applications in everyday-domains such as education and medicine?

6) Do you think there are risks resulting from the neuroscientific research?

The majority of the participants reported that they find the neurosciences more important than other disciplines ('very important' 26.7%, n = 81, 'rather important' 66.0%, n = 200, 'rather unimportant' 5.0%, n = 15, 'very unimportant' 2.3, n = 7). In addition, respondents rated the neurosciences better capable of explaining mental states than other disciplines ('yes' 19.9%, n = 60, 'rather yes' 63.9%, n = 193, 'rather no' 13.6%, n = 41, 'no' 2.6%, n = 8).

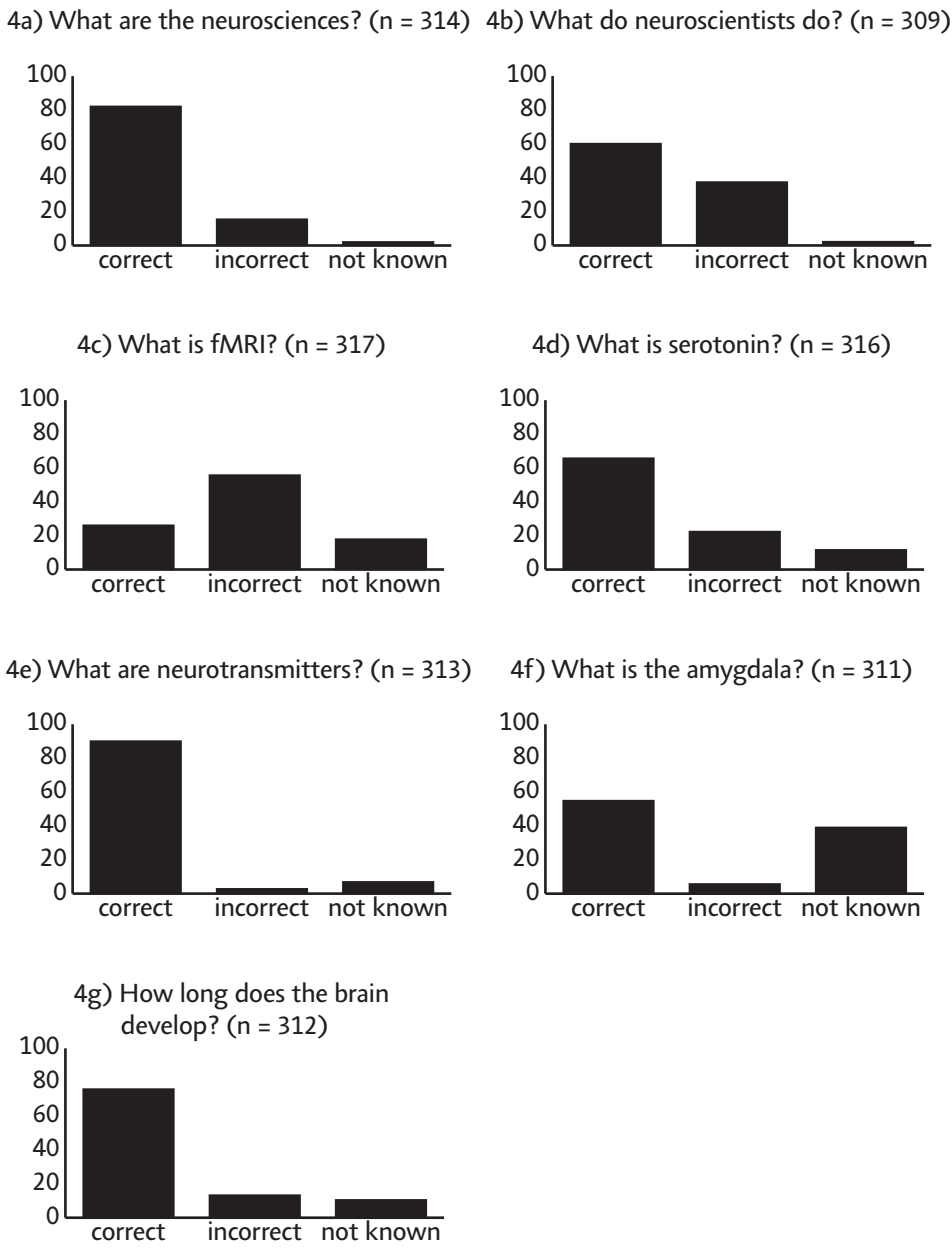

Fig. 4 Participants' responses to knowledge questions about the the brain and the neurosciences

When asked how significant the neurosciences are for the participant's everyday life, only 7.4%, n = 23 reported that they were 'very important' and 47.7%, n = 148 that they were 'rather important' ('rather unimportant' 40.3%, n = 125, 'very unimportant'4.5%, n = 14). Participants had an overall high trust in science ('very much' 7.8%, n = 24, 'strongly' 78.8%, n = 242, 'not very much' 11.1%, n = 34, 'not at all' 2.3%, n = 7). With regard to the neurosciences' potential for everyday-life applications 26.8%, n = 84 of the participants considered it to be 'very high', 63.3% 'high', n = 198, 8.9%, n = 28 that it is 'rather low', and 1.0%, n = 3 that it is 'very low'.

Participants indicated that they saw 'rather no' risks (50.5%, n = 156) resulting from the neurosciences, followed by 11.7%, n = 36 who answered 'no', 19.4%, n = 60 who answered 'yes', and 18.4%, n = 57 who answered 'rather yes'. Table 1 shows exemplary replies from participants who saw potential risks resulting from the neurosciences.

Table 1 Respondents' answers regarding their opinion about potential risks coming from the neurosciences

'Please **no** selection of people.'
'popular distribution of insecure knowledge'
'basis for brainwashing'
'With too much knowledge about the brain one could determine a loss of the importance of ethical boundaries and exceed them. That for example thought can be manipulated or documented.'
'man could be disenchanted, because feelings, thoughts and individuality are more and more reduced to neuronal processes'
'Putative findings that prove to be incorrect at a later time, but which were cemented into society/medicine/science…'
'the idea that thoughts are free could at some point no longer hold'

Area 3. Beliefs about the alterability of the brain and its capacities – and resulting behaviour

A specific focus of this questionnaire was to assess participants' thoughts about the alterability of the brain and its capacities. This area of interest was comprised of the following questions:

1) Did you ever hear about the plasticity of the brain?

2) Do you think the brain can be influenced?

3) Do you think that the brain can be altered by your own will and power?

4) Do you think it is possible to learn something new with high age?

5) Do you think it is possible to prevent from diseases like Alzheimer's disease or Parkinson's disease?

6) Do you believe that your personality is stable and can stay persistent over time?

7) Do you think that you can change your brain to become happier?

8) Are you doing something to keep your brain fit?

9) Did you ever use any kind of computer software in order to keep your brain fit?

The majority of the participants did not know the concept of brain plasticity ('no' 63.5%, n = 193, 'yes' 36.5%, n = 111), but they believed that the brain can be altered in general ('yes' 64.5%, n = 193, 'rather yes' 32.1%, n = 96, 'rather no' 2.7%, n = 8, 'no' 0.7%, n = 2) and by one's own will and power ('yes' 33.2%, n = 100, 'rather yes' 43.2, n = 130, 'rather no' 19.9, n = 60, 'no' 3.7%, n = 11). 73.5%, n = 219 of the participants believed that it is possible to learn something new with high age ('rather yes' 21.1%, n = 63, 'rather no' 4.4%, n = 13, 'no' 1.0%, n = 13). Participants were optimistic about the possibility to prevent from neurodegenerative diseases like Alzheimer's or Parkinson's disease ('yes' 22.3%, n = 65, 'rather yes' 46.4%, n = 135, 'rather no' 27.5%, n = 80, 'no'

3.8%, n = 11). The majority of participants indicated to believe that personality is stable and stays persistent over time ('yes' 13.0%, n = 39, 'rather yes' 56.8%, n = 171, 'rather no' 22.3%, n = 67 'no' 7.9%, n = 24). Furthermore, many participants believed that it is possible to become happier by changing one's brain ('yes' 22.1%, n = 66, 'rather yes' 40.1%, n = 120, 'rather no' 27.8%, n = 83, 'no' 10.0%, n = 30). Table 2 shows participants' ideas about ways how the brain can be altered.

Table 2 Participants' opinions about how the brain can be altered

'train specific skills such as empathy, perseverance'
'"Switching" the neural network in a different way. Create connections, destroy others. Modify the "mind", so to speak.'
'Through regular training (like with a muscle) of the short term memory, working memory and logical thinking.'
'Not at all, you can change your mindset, but not your brain.'
'Try out new things that you usually would not do and which demand different brain resources as activities that one usually performs.'
'stay curious, give the brain "food" '
'surgical, medicamentous, sensory input'

Furthermore, participants were asked about their opinions regarding free will and decision-making. This topic received frequent media coverage in Germany in the last years.

The majority of participants believed to possess free will ("Do you think you have a free will?", 'yes' 33.2%, n = 99, 'rather yes' 48.7%, n = 148, 'rather no' 13.1%, n = 39, 'no' 5%, n = 15). Most of the participants disagreed that their actions are determined ("Do you think that your actions and decisions are determined?", ('yes' 2.0%, n = 6, 'rather yes' 12.2%, n = 36, 'rather no' 45.9%, n = 136, 'no' 39.9%, n = 118) and that the neurosciences can improve their decision-making ("Do you think that the neurosciences can help you to make better decisions in order to become who you want to be?", ('yes' 4.0%, n = 12, 'rather yes' 29.0%, n = 86, 'rather no' 41.8%, n = 148, 'no' 25.2%, n = 75).

Participants did not believe that the neurosciences can improve decision-making. However, they assumed that they bear more responsibility for themselves when knowing more about how to improve themselves. ("Do you think that you will have more responsibility for yourself if you have more knowledge about how you can improve your

capacities?", ('yes' 28.2%, n = 83, 'rather yes' 46.3%, n = 136, 'rather no' 16.3%, n = 48, 'no' 9.2%, n = 27)).

In addition to asking whether participants believe that the brain is malleable, we further assessed how participants evaluate the consumption of brain altering nutrition and substances, and whether participants actively try to change their brain and cognitive capacities (Figure 5 and Figure 6). The majority of participants believed that the brain can be influenced by certain substances and by nutrition (Figure 5). Further, participants were asked about how often they consume specific nutrition and substances in order to influence cognitive functions. In comparison to drugs that improve concentration and other cognitive capacities which were rarely consumed, participants frequently consumed nutrition with the goal to "enhance" their cognitive capacities. Participants most often consumed substances such as caffeine in order to improve their concentration ('daily' 63.9%, n = 101 from n = 158 stated) followed by specific food in order to improve their cognitive capacities ('daily' 39.4%, n = 52 from n = 132 stated), and supplements that are said to improve one's concentration ('daily' 32.3%, n = 20 from n = 62 stated). Some participants reported to consume drugs to improve their mood ('daily' 19.7%, n = 15 from n = 76 stated) or drugs to improve their cognitive capacities ('daily' 15.2%, n = 5 from n = 33 stated). However, besides coffee most participants did not consume further specific substances in order to improve cognitive capacities or to regulate their mood. Given that there were many missing values, wider inferences should be treated with caution.

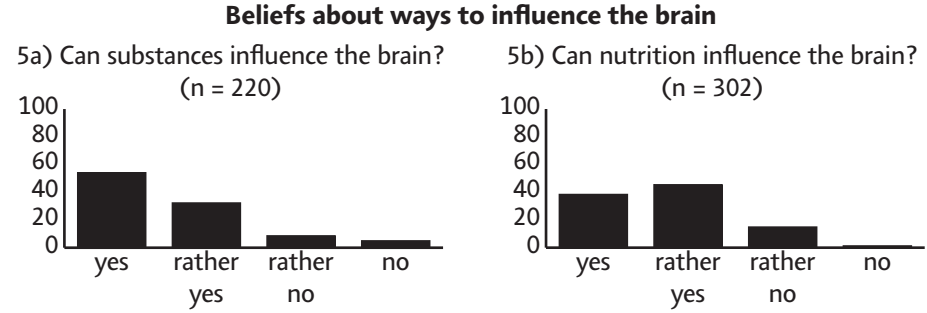

Fig. 5 Participants' responses to questions about their ideas about how the brain can be influenced by consuming substances. The questions were 5a) Do you believe that certain substances (e.g. coffee etc.) can influence your brain? and 5b) Do you believe that your nutrition has influences on your brain?

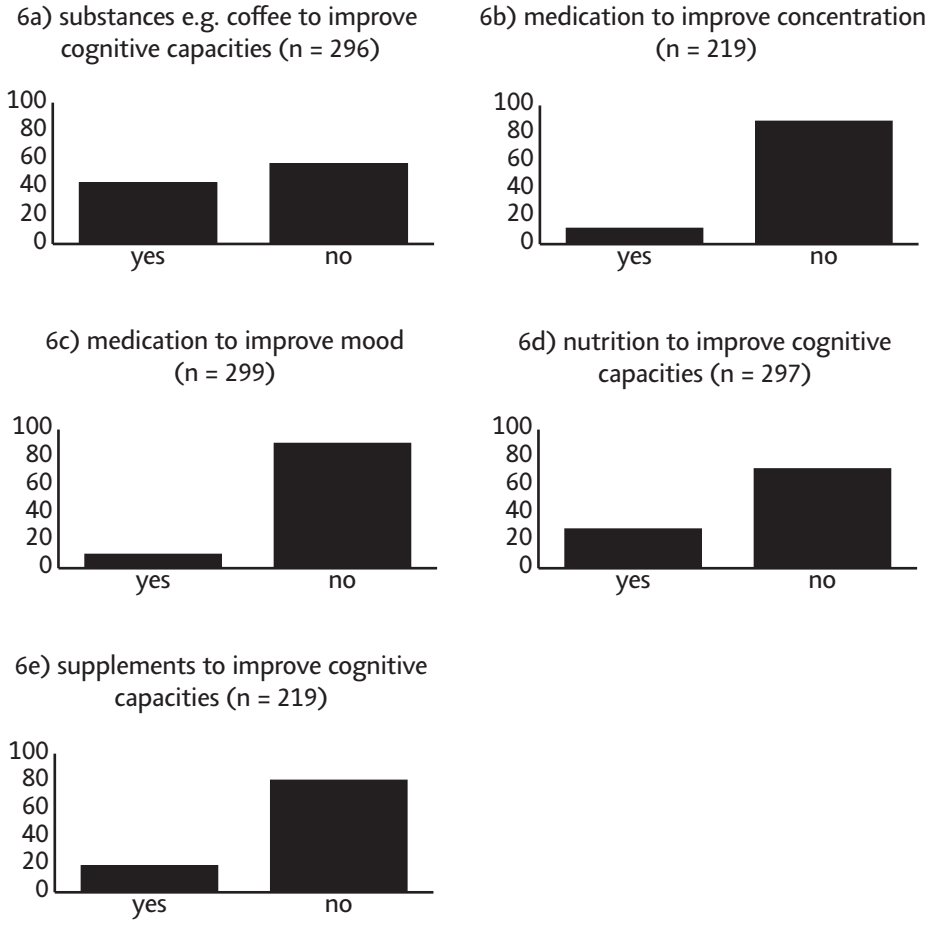

Fig. 6 Participants' responses about their consumption behaviour of substances that can improve cognitive capacities

We were interested in whether participants engage in any other activities besides nutrition in order to keep their brain fit. Therefore, we asked participants to list any activities that they perform to train their brain. Table 3 shows a list with a selection of different kinds of methods and activities that participants employ in order to maintain and improve their mental capacities.

Table 3 Participants' suggestions and experiences about ways to maintain and improve mental capacities

'live in a diversified way ('read, love, walk')'
'occasionally "brain training", generally through continuous thinking, prevent from "stagnation"'
'meditation and music'
'sports and movement, reading, proper alternation between tension and relaxation, perceive new things as enrichment'
'I can change my behaviour (e.g. more sports) → my brain changes (more happiness hormones) → I am happier'
'playing piano, doing origami and sports for my serotonin'
'before, I said that one cannot change ones brain with one's own power or will, but still I believe that there is much one can do'
'sunlight, vitamin D, music, positive thinking'
'medication, strong willpower, help of others'

Area 4. Beliefs and opinions about the relation between the neurosciences and societal topics

4.1 Agreement on statements about the brain and neurosciences

To study participants' beliefs and opinions about how the neurosciences relate to individual and societal issues, we asked participants to rate how much they agree with statements about this relation. Table 4 shows participants' agreements on 31 statements about the interrelations of brain, mind, environment, and society. Participants had to rate the statements using a six graded Likert scale with answer options from 'very low', 'low', 'rather low', 'rather high', 'high' to 'very high'.

Table 4 Participants' attitudes towards statements about the relationship between neurosciences and societal topics. Ratings are ordered by the size of the mean. Highest ratings are on the top of the table and the lowest ratings are on the bottom of the table.

* Due to technical difficulties no data were recorded for this item.

Statements	Mean	Standard Deviation
brain controls mind	5	1.049
brain controls emotions	4.82	1.039
brain controls ability to work	4.73	1.001
neurosciences can help to cure diseases like Alzheimer's or Parkinson's disease	4.68	1.116
environment can change the brain	4.66	1.143
everyone can use certain kinds of training to better concentrate	4.64	0.998
family can change the brain	4.51	1.271
a healthy lifestyle can improve how my brain works	4.48	0.897
everyone is responsible for having a healthy brain	4.46	1.143
more profound knowledge about the brain can lead to better health	4.44	1.221
neurosciences can help to better explain how people behave	4.37	1.071
neurosciences can help to improve the educational system and how children learn	4.33	1.153
media can change the brain	4.31	1.188
brain controls body	4.14	1.156
everyone can use certain kinds of training to be more emotionally stable	4.14	1.191
environment influences the body	4.09	1.175
neurosciences can help to improve the education of children	3.99	1.203
everyone is responsible for their own health	3.98	1.124
neuroscientific research covered in the media is comprehensible	3.8	1.129

psychology can better than neuroscience explain why people are depressed	3.61	1.068
neuroscientific research is important for my everyday-life	3.61	1.272
neuroscience can better than psychology explain why people are depressed	3.56	1.134
everyone can use medication that influences the brain and improves one's concentration	3.21	1.341
everyone can use medication that influences the brain and enhances one's mood	3.2	1.362
neurosciences are important for religious beliefs and spirituality	2.9	1.459
neuroscientific findings require to change the law system	2.84	1.298
neuroscientists can show that there is no free will	2.63	1.311
environment influences emotions	0.77	1.767
environment influences cognitive capacities	0.75	1.733
culture can change the brain	0.74	1.704
more profound knowledge about the brain can help to better understand diseases	----*	----*

4.2 Influence of the neurosciences on societal topics

Finally, we asked the participants to give their overall judgement on whether neuroscientific research has the potential to lead to new insights in 19 different areas (Figure 7). Participants could rate on a six graded Likert scale from 'very low', 'low', 'rather low', 'rather much', 'much' to 'very much'. Participants rated that neuroscientific research would be most influential for understanding neurological diseases (mean = 5.25), memory (mean = 5.13), and thinking (mean = 5.02). They judged that neuroscientific research would have the least influence in areas relevant to faith and religion (mean = 3.03), law (mean = 3.20), and art (mean = 3.58).

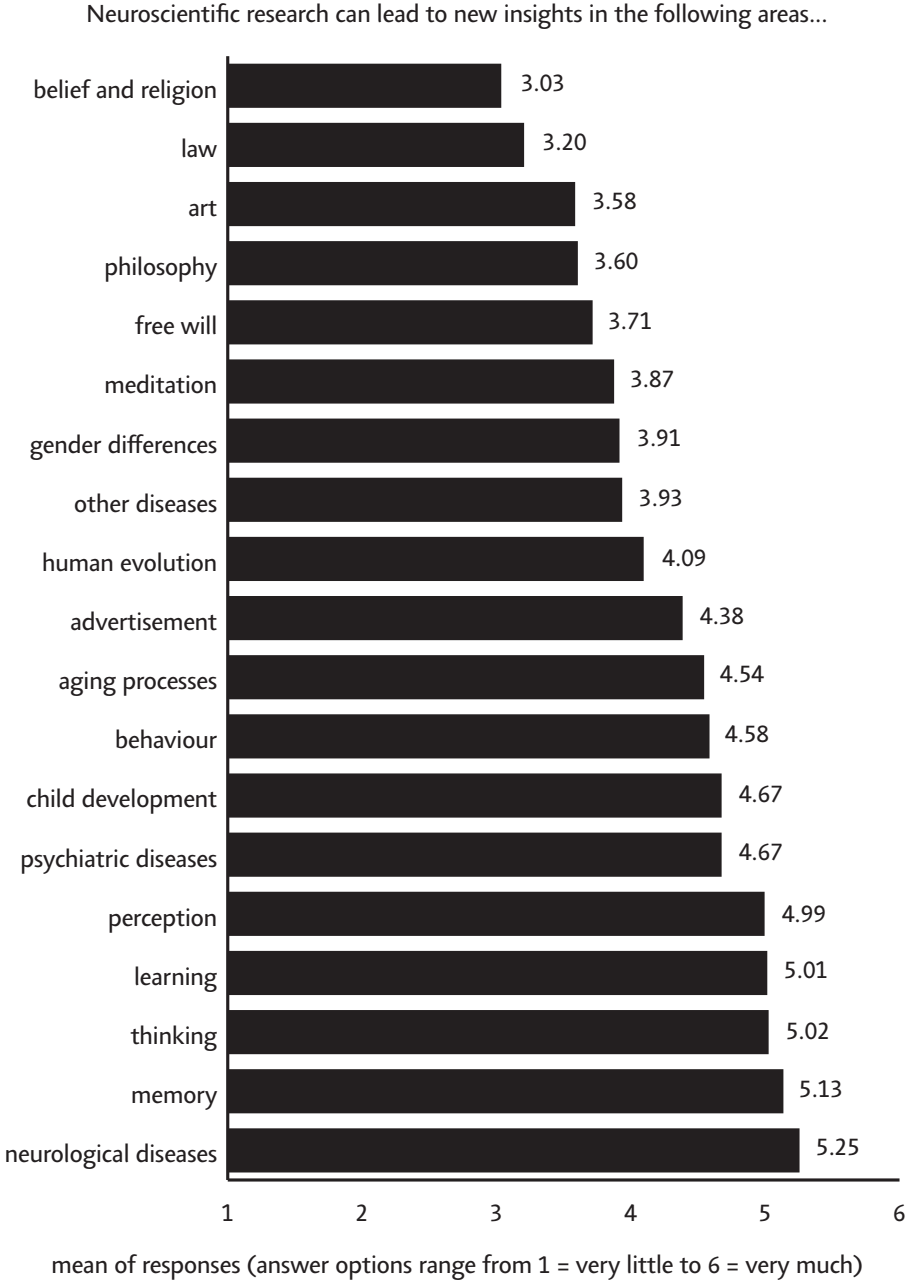

Fig. 7 Participants' ratings on statements about the influence of neuroscientific research in different areas

Discussion

The overall goal of this explorative study was to investigate a wider public attitudes and perceptions of the neurosciences and particularly the topic of neuroplasticity within the German population. In order to get a first impression about how the wider public perceives the neurosciences we focused on the participants' interest and knowledge about the brain (first area of interest), what participants believe about the neurosciences (second area of interest) and what they know and think about the alterability of the brain in particular (third area of interest). Finally, we assessed the participant's attitudes on the relationship between several societal topics and the neurosciences (fourth area of interest).

Participants of the current study reported to be highly interested in the brain with a strong emphasis on topics related to general brain functioning, learning, memory, and health-related issues. In addition, participants showed to have moderate knowledge about basic neuroscientific facts and rated that the neurosciences are more capable to explain mental states than other disciplines. These findings provide evidence that our sample is interested in how the brain functions in domains related to health, ageing and learning. Future studies should gather further empirical data about the reasons that motivate a wider public to be interested in these particular topics and to increase their knowledge about brain functions within these domains. One potential motivation could be an interest to use this knowledge in order to sustain and enhance their health and cognitive functions. This explanation is supported by a recent study showing that laypeople only integrated information from brain research that were linked to clinical topics such as neurological diseases (O'Connor and Joffe 2014).

The results from the second area of interest showed that the respondents have a positive attitude towards the neurosciences and regard them as important for their everyday life. Interestingly, it has been argued that narratives that include neuroscientific facts are perceived as more objective and granted as more authoritative (Joyce 2005). Eric Racine and colleagues (Racine, Bar-Ilan, and Illes 2005) identified several so-called 'neuro-realist' narratives in the public press and emphasized that neuroscientific knowledge communicated through the media can have far-reaching influences on the society. The results from the present study may indicate that the wider German public is influenced by the partly 'neuro-realist' media coverage of neuroscientific findings.

Finally, participants reported to generally trust in science and did not expect many risks resulting from neuroscientific research. To better understand why participants have a generally positive perception of the neurosciences, it is worthwhile to further investigate how this positive view about the neurosciences comes about and whether the wider

public critically reflects on knowledge obtained through the neurosciences. Does the wider public use knowledge about the brain to justify their own behaviour, and do they critically question how the media covers neuroscientific findings? Future studies could investigate how much the public understanding of neurosciences deviates from the actual scientific findings as reported by the scientists. Findings from such investigations could extend the understanding about how well the lay public receives science communication (Wardlaw et al. 2011, O'Connor and Joffe 2014).

The alterability of the brain and of cognitive capacities is currently a crucial and much investigated topic in the neurosciences. Research about neuroplasticity provides evidence that neuronal structures are more malleable and dynamic than formerly believed (Buonomano and Merzenich 1998, Münte, Altenmüller, and Jäncke 2002, Pascual-Leone et al. 2005, Kauer and Malenka 2007, Dayan and Cohen 2011, Davidson and McEwen 2012, Sagi et al. 2012, Jäncke 2009, Fuchs and Flügge 2014). While this evidence is particularly important for clinical purposes such as rehabilitation, it also finds its way into the areas of education, music, sports, and human development (Münte, Altenmüller, and Jäncke 2002, Jäncke et al. 2009), and into the so-called neurocultures (Frazzetto and Anker 2009, Rose and Abi-Rached 2013). Neuroplasticity research can have wider implications for topics such as responsibility, autonomy, control of behaviour, and shaping the personality of individuals. Knowledge about neuroplasticity can influence thinking about how to lead one's life and how to understand one's responsibility for it (Malabou 2009, Nagel 2013, Nagel and Reiner 2013). The majority of participants from the current study did not know about the concept of neuroplasticity, but they nevertheless believed that the brain can be altered in general. More specifically they believed that the brain can be altered by one's own "will and power". These findings match the participants' belief in having free will and the belief that one can become happier by changing one's brain. Notably, at the same time, participants reported that one's personality is stable and does not change over time.

The respondents' belief that one can become happier by changing one's brain and that one's personality is persistent over time suggests that their ideas about the connection between personality and the brain are complex. Future studies with more refined questions could help to disentangle these questions. Respondents believed that they can alter their brain with nutrition and substances such as coffee. Their consumption behaviour of nutrition and supplementary substances to influence their brain is particularly evident from their descriptions on how they understand food to be beneficial for their brains. This fits well to a general trend to consume nutritional supplements to enhance health and mental functioning (Ritchie 2007).

The fourth area of interest studied participants' evaluations of statements about the relationship between brain, behaviour, and environment and the neurosciences' potential to lead to new insights in societal domains. Participants rated that the neurosciences can lead to new insights about thinking, memory, disease, but also about gender differences and child development. Respondents agreed that the neurosciences can inform about gender differences. Notably, a meta-analysis about how the media presents neuroscientific research (O'Connor, Rees, and Joffe 2012) found that media narratives about neuroscientific findings support existing gender stereotypes.

The respondents' ratings of the statements about the relation between brain, behaviour, and environment showed manifold inconsistent answers. While participants agreed that the brain controls the mind, emotions, and the ability to work and that the environment can change the brain, they at the same time mainly disagreed that the environment can influence cognitive capacities, emotions, and that culture can change the brain. Moreover, it should be taken into account that participants believed to have free will (second area of interest). O'Connor and Joffe (2013) provided evidence that the public representation of the neurosciences does not scrutinize how personality, society, and behaviour are perceived and also provides empirical support for this claim (O'Connor and Joffe 2014). The apparent mismatch of beliefs from our respondents might suggest a shift in traditional beliefs about personality and society. At the same time it is important to note that the vast majority of our respondents were not trained in philosophy and thus could have well been somewhat confused by the delicate relationship between mind and brain – a topic that is hard to grasp in a short survey. While participants seem to adopt traditional views about the stability of personality, free will, and the brain's control of mental processes, they also believe that it is possible to become happier and improve their cognitive capacities by altering their brains. The study did not explore how participants conceptualized terms like environment, culture, cognitive capacities, and emotions. Interpreting these answer tendencies is difficult, and future studies should take this into account.

These findings demonstrated that the wider public is engaged with neuroscientific topics, which calls for further investigation. For the field of neuroethics, studies of how people understand themselves in lights of neuroscientific work and its medial presence, what they think about technological impacts, what they hope for and fear, will provide a helpful measure to nuance ongoing debates and suggest new fields to inquire. Noticing and discussing intuitions of a wider public in particular of those who are not trained in any of the fields of neuroethics can deepen normative deliberation. Policy debates

and regulatory institutions in their efforts for sound decision-making will benefit from knowledge about the public's expressions concerning the emergence of the neurosciences.

The neurosciences have the potential to influence individual and societal life in many different ways. Hence, it is important to discuss how neuroscientific knowledge might transform the way we live and understand ourselves. How neuroscientific research influences the wider public can be multifaceted, and is neither good nor bad per se. It is important to discuss the potential influences, and the inclusion of the public and experts from different fields is central to this discussion (Sarewitz 2010). Directly asking the wider public about how they perceive the neurosciences, and how they make use of neuroscientific knowledge, strongly enriches discussions about neuroscientific implications for society. Gathering more data on how the wider public integrates neuroscientific knowledge into their everyday-life will help our understanding, e.g. on how sciences influence decision-making, sense of self, and moral responsibility (Nadler and Reiner 2010). Furthermore, such studies shall also contribute to investigate how the public understanding of the neurosciences is related to policy making in clinical domains and recommendation of politics for law-making (Zimmerman and Racine 2012). To enrich the discussions about how the neurosciences might influence society we recommend to consider the following aspects for future studies: It is well possible that people with different cultural backgrounds, clinical populations, expert groups, adolescents, and elderly might perceive and are influenced by the neurosciences in different ways. The results of our current study could be specific to the German culture but also to the highly educated sample. A more representative sample should include participants from different age groups, educational and cultural background (Henrich, Heine, and Norenzayan 2010, Wardlaw et al. 2011). Qualitative data could be further analyzed with detailed narrative analyses as used by Rodriguez (Rodriguez 2006) to show whether our common sense knowledge about how we behave is influenced by the neurosciences. Moreover, studying the coverage of neuroscientific research by the general media, i.e., not only the media working on the neurosciences, could be accompanied by studies about the public perception of these types of media and vice versa. Finally, improving the communication and interaction of the sciences with the media is an important goal. Improved communication could be realized by discussions between scientists and journalists about how specific neuroscientific research findings might create specific narratives and folk psychological beliefs about the relationship between brain, mind, and behaviour. Overall, a sensitive media coverage can help the public to question neuroscientific results as presented in the media (Hasler 2012), and critically evaluate the

advertisements and industrial products that sell their effectiveness using neuroscientific findings.

Conclusion

The neurosciences currently seem to be perceived as being among the most important scientific disciplines. This is reflected by their frequent public media coverage, but also by emerging technologies based on research in the neurosciences. Due to the neurosciences' potential to influence society in diverse ways, it is important to gather and evaluate data about how a wider public perceives the neurosciences and their applications. Investigating to what extend neuroscientific knowledge influences the way people behave, and how it influences their sense of responsibility, autonomy, and free will, can serve to inform policy-making. The results of the presented survey call for a broadening and nuancing of the research about the public perception and evaluation of the neurosciences in order to clarify the manifold interrelations between science and society.

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