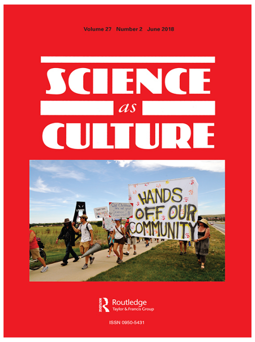

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Constituting 'Visual Attention': On the Mediating Role of Brain Stimulation and Brain Imaging Technologies in Neuroscientific Practice

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ABSTRACT

An important development within cognitive neuroscience is the use of *Non-Invasive Brain Stimulation* (NIBS), a technique which holds the promise of establishing causal relationships between brain processes and cognitive processes. However, NIBS does not allow researchers to *observe* neurophysiological processes, and must be coupled with imaging technologies such as *Electroencephalography* (EEG) for the visualization of neurophysiological change. Technologies such as NIBS and EEG are not neutral intermediaries between scientists and the world, but actively mediate the reality that scientists investigate. How these technologies shape the objects of neuroscientific study becomes clear when analyzing real-life conversations between neuroscientists researching visual attention. During the constitution of visual attention, neuroscientists need to manage a tension between the epistemic norms of 'causality' and 'reality', and how this tension is managed differs when different technologies are used. In the case of NIBS, the tension between reality and causality is managed in terms of the relation between experimental results obtained within the laboratory and the 'real' world *outside* of the laboratory. When NIBS and EEG are combined, neuroscientist orient to the norms of causality and reality in a different way: now, the reality of the causality obtained *within* scientific experiments needs to managed. This indicates that neuroscientists cannot straightforwardly assume the causal efficacy of the brain on human behavior. Instead, the coming into being of neuroscientific objects such as visual attention is both dependent on technological mediations and on how the tension between the norms of 'causality' and 'reality' is managed.

KEYWORDS
Non-Invasive Brain Stimulation; technological mediation theory; cognitive neuroscience; postphenomenology; conversation analysis; philosophy of technology

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Introduction

The promise of cognitive neuroscience is to explain human cognition in terms of its underlying neurophysiological interactions. A driving force in the development of this scientific domain is the idea that a unified theory of the human mind can be established with the help of the neurosciences. This is reflected in proposals for projects such as *Mindscope* (Koch *et al.*, 2015) and *The Decade of the Mind* (Albus *et al.*, 2007). Typically, it is stressed that the neurosciences have the potential to mitigate human suffering from mental and physical neurological diseases by developing 'a mathematical and predictive framework of how all elements [of the brain] fit together and act as a whole to give rise to intelligence and consciousness' (Koch *et al.*, 2015, p. 39).

Brosnan and Michael (2014) have argued that this promise of merit in the future binds different neuroscientific practices together and allows for the existence of 'neuro' to endure. In this paper, we will study an important development within cognitive neuroscience that embodies such a promise: *Non-Invasive Brain Stimulation* (NIBS). To do so, we followed a group of cognitive neuroscientists who are among the first to combine *Electroencephalography* (EEG) with several forms of NIBS in the study of visual attention. Our analysis addresses the following research question: how is the scientific object 'visual attention' constituted in the interactions between scientists that collectively relate to NIBS and the combination of NIBS and EEG?

From its early use onwards, the promise of NIBS is to establish *causal* relationships between brain processes and cognitive processes by stimulating the brain and observing the corresponding behavioral change (Walsh and Cowey, 2000; Sack, 2006). In this way, it is thought that neurophysiological processes that are functionally relevant to particular cognitive processes can be identified. However, NIBS does not allow researchers to *observe* neurophysiological processes, and must be coupled with imaging technologies such as *functional Magnetic Resonance Imaging* (fMRI) or EEG for the visualization of neurophysiological change (Miniussi *et al.*, 2013, Hermann *et al.*, 2016).

In this paper, we show that EEG, NIBS, and the combination of NIBS and EEG each give rise to a different constitution of visual attention, of which the reconcilability is not self-evident. The different technologies do not so much offer different perspectives on one singular object that can be identified as 'visual attention', but rather make scientists relate to different provisional objects that need to be actively stabilized. As we show, the relation to these objects is mediated by the specific technologies that are used. We argue that the norms that scientists orient to when relating to the human brain differ per technology, which undermines the idea that the use of different technologies will eventually converge into one coherent picture of cognitive phenomena such as visual attention.

In order to show this, we will first introduce a framework to analyze the role of technologies in neuroscience, based on the approach of postphenomenology, arguing that the reality that scientists investigate is mediated by the technologies they use. After this, we will show that postphenomenology has rightly emphasized the role of technologies in the construction of scientific objects but lacks empirical translation. To fill this lacuna, we relate postphenomenology to empirical studies of (neuro)scientific practice, and suggest that a postphenomenological framework augmented with insights from *Conversational Analysis* (CA) provides a fruitful way to study how 'human cognition' is constituted in neuroscientific practice. After developing this theoretical framework, we discuss how we collected our data and the methods we use in our analysis and provide an explanation of the technical details necessary for a basic understanding of cognitive neuroscientific research into visual attention.

Our analysis shows that NIBS and the combination of NIBS and EEG technologies make researchers strongly orient to a norm of causality that is weighed against the norm of reality, thereby actively shaping how visual attention is constituted in neuroscientific practice. The norms of causality and reality are weighed against one another differently when scientists relate to different technologies. We show that, in the case of NIBS, the tension between reality and causality is managed in terms of the relation between experimental results obtained within the laboratory and the 'real' world *outside* of the laboratory. Subsequently, we show that the combination of NIBS and EEG mediates how neuroscientists orient to the norms of causality and reality: now, the reality of the causality obtained *within* scientific experiments needs to managed. We conclude by arguing that the norms of causality and reality to which researchers orient during the constitution of visual attention are not explicit norms that are straightforwardly complied with, but are implicitly oriented to when constituting visual attention as a neuroscientific object.

Technological Mediations and their Appropriations

In modern science, objects of research typically become visible to scientists in interaction with technological instruments. For instance, observing the human brain is impossible without imaging technologies such as *Computed Tomography* (CT) and *Magnetic Resonance Imaging* (MRI). Similarly, observing human cognition in neuroscientific terms depends on technologies like fMRI, EEG, and NIBS. These technologies play a central role in translating relevant phenomena into candidates for human interpretation. In the words of the postphenomenologist Don Ihde, a '*translation* is a technological transformation of a phenomenon into a readable image. This is one analog to a hermeneutic process, except in this case it is a *material* hermeneutic process' (1991, p. 56). These translations can be understood as *technological mediations* that structure how reality becomes perceptible to scientists (Ihde, 1991, 1998, 2009). Ihde suggests that, in order to understand modern scientific practice, we must focus on these hermeneutic processes that give rise to the existence of scientific objects.

Although technologies help to shape relations between scientists and the reality they study, they do not *determine* the objects of research. Rather, technologies *mediate* the reality that scientists study: in the relation between humans and technologies, a specific knower (subject) and thing known (object) are constituted, but the structure of the relation between the two is not fixed (Verbeek, 2005, p. 130). Different technologies disclose the reality that scientists study differently, and constitute different types of scientific observers. From this perspective, understanding how scientists relate to technologies becomes a way to understand how scientists and the objects they study mutually constitute one another. Ihde emphasizes that technologies make reality perceptually present in a specific way, and understands technological mediations in scientific practice in terms of the constitution of a specific perceptual object that becomes visible for an embodied observer. This has inspired postphenomenological studies showing how images condition debates in the neurosciences (Rosenberger, 2011), and on how scientific observations of the surface of Mars are mediated by imaging technologies such as the Mars Orbiter Camera (Rosenberger, 2008, 2013).

In emphasizing the actively mediating role of technologies, the postphenomenological approach has tended to overlook how human beings subsequently understand and act upon these mediations. Analyses of technological mediations deserve to be complemented with analyzing human appropriations *in actu* (Verbeek, 2016, p. 191). The constitution of visual attention as an object of research not only depends on how brain activity becomes perceptually present through technological mediations, but also on how groups of scientists collectively appropriate these mediations. As will be discussed in more detail below, we suggest that CA allows us to capture both the implicit and explicit ways in which technological mediations are appropriated *in actu* (cf. Ibid., p. 195).[1] Thus far, the empirical study of how technological mediations are appropriated in scientific practices, has not been a central concern in postphenomenology. In this article, we take up the challenge of studying how technological mediations are appropriated by conducting an empirical study of how visual attention is constituted in neuroscientific practice.

Technologies and Neuroscientific Practice

The empirical study of laboratory practices has been one of the central interests of *Science and Technology Studies* (STS) from its early days onwards (e.g. Knorr-Cetina and Mulkay, 1983; Gilbert and Mulkay, 1984; Latour and Woolgar, 1986; Knorr-Cetina, 1999). Interest in neuroscientific practices increased after the designation of the *Decade of the Brain* (1990–1999), a large, publicly funded big science project devoted to the study of the human brain (e.g. Littlefield, 2009; Littlefield and Johnson, 2012; Pickersgill and Van Keulen, 2012). Since the increased popularity of the neurosciences is closely related to technological developments to visualize brain processes *in vivo*, primarily the role of brain imaging technologies in scientific practices has been subject of investigation (e.g. Beaulieu, 2002; Joyce, 2006). Critical studies have focused on how neuroscientists unjustifiably tend to reduce human beings and personalities to their underlying neurophysiology (e.g. Dumit, 2004; Choudhury and Slaby, 2012).

Furthermore, it has been shown that brain scans should not be understood as allowing to 'peak into the human mind', but that understanding human cognition in terms of its underlying mechanisms is dependent on active processes of human interpretation (e.g. Roskies, 2007). For example, it has been shown that the 'seeing' of brain scans is not a disembodied cognitive act, but involves active multimodal embodied engagement (Alaç, 2008), which is indicative of the tacit knowledge needed to interpret brain scans (Gross, 2009; Heiberg Engel, 2008). While such analyses convincingly show that the interpretation of brain scans presupposes a specific social and embodied organization, they often surpass the question of how technologies help shape the *objects* of scientific research. In this study, we examine this question by investigating how visual attention is shaped in the relations between humans and technologies. We focus on how brain imaging technologies constitute the scientific object 'visual attention' in a very specific way, and shape how it becomes a reference point of collective orientation. From this perspective, scientific objects are never fixed entities, but rather *tentative* objects that are subject to continuous revision.

Conversational Analysis and Normative Accountability

We use CA to study the constitution of visual attention. CA (Lynch, 1985, 1988; Sacks, 1992; Te Molder and Potter, 2005) is related to ethnomethodology, and studies from a participants' perspective how people use language as a medium to construct a reality in which meaningful actions are performed. Like ethnomethodology, CA is interested in the rules and norms that people use and hold each other accountable for. Ethnomethodology (Garfinkel, 1967) and CA (Sacks, 1992; Te Molder and Potter, 2005) define practices as deeply and inherently normative.

Being able to show *how* everyday practices normatively constitute their own reality requires to consider them as radically situated within local practices. As Harold Garfinkel puts it: 'local practices are not texts which symbolize "meanings" or events. They are in detail identical with themselves, and not representative of something else' (Garfinkel, 2002, p. 97). Accordingly, conversation analysts and ethnomethodologists hold that normativity is not so much the consequence of people obeying certain rules external to the practice they engage in, but rather is constituted by the fact that people *orient themselves towards* norms. Actions are described in ways that display their status with regard to some rule or expectation. When categorizing events as departing from some normative order, people account for that deviation, thereby making routinely hidden norms available for inspection by researchers (Heritage, 1984, pp. 115–120). These norms are therefore constitutive of the reality organized from within local practices. For example, local hierarchies and power relations (e.g. differences between novices and experts or between PhD students and their supervisors) can become visible when showing how conversational participants hold each other mutually accountable for them.

In line with recent ethnomethodological studies inspired by CA, we show that the coming into being of scientific objects can be understood as a *practical accomplishment* constituted from within local practices. That is, scientific objects such as visual attention 'emerge and [are] established, perceived and understood, *from* processes and trajectories of social interaction' (Nevile *et al.*, 2014, p. 17). CA allows us to analyze interactions between scientists in real-time, which enables us to show the norms to which they orient in the active constitution of visual attention. Because these norms are constantly (re-)negotiated, visual attention is not interpreted as a rigid entity, but as an accomplishment that is subject to continuous change (Koschmann and Zemel, 2014; Nevile *et al.*, 2014).

In our analysis, we situate the practical accomplishment of visual attention within the specific project taking place in the laboratory environment: using NIBS and NIBS-EEG to causally link brain processes to visually attentive behavior (described in more detail in the section "NIBS, EEG, and Visual Attention"). We show that the constitution of visual attention takes place by managing a tension between the epistemic norms of 'causality' and 'reality'. Researchers make themselves accountable for (1) that certainty is required in order to causally link the observed brain activity to NIBS, and (2) that certainty is required to claim that the observed brain activity is demonstrative of the reality of visual attentive behavior. As will become clear throughout our analysis, how the tension between these epistemic norms is managed when using NIBS, significantly differs from how it is managed in the case of NIBS-EEG.

Data and Method

As data, we used video recordings of discussions between members of a group of researchers in the cognitive neurosciences during their weekly lab meetings. The material was recorded over a period of two months. We transcribed and examined the recordings with a primary focus on the verbal exchanges. A supplementary analysis of the video material was performed wherever it appeared necessary for a full understanding of what was said and done. The names of the participants have been altered, and the date and time indications have been deleted to minimize the possibility of identification. Institutional ethical approval was granted before the period of data collection. The data corpus consists of recordings of 5 lab meetings, adding up to a total of approximately 500 min of recorded material.

The recorded meetings were transcribed using ELAN.[2] The main part of the data corpus was transcribed to a words-only level, but relevant parts were transcribed in more detail, using Jeffersonian transcription notation (Jefferson, 2004: see Appendix 1), including the pauses and overlap between speakers. The original conversations were in English, but most participants were non-native speakers. We have not translated the conversations into grammatically correct sentences because this would undermine the objective to study the constitution of objects in real-life conversations among participants.

In line with the principles of CA, our approach has been participant-centred, i.e. we looked at how participants in the conversation actively constructed a meaningful reality (Lynch, 1993). In addition, we started with the assumption of technological mediation theory that taking technologies (such as NIBS or EEG) into account is crucial when it comes to understanding the constitution of scientific objects. Accordingly, our analysis has focused on those elements in the conversations where the relation between the use of a particular technology, and the constitution of visual attention was subject of discussion. Thus, rather than being representative of all of the topics discussed within the entire corpus of recorded conversations, we take the selected excerpts to be representative examples of how visualizations of brain activity are made relevant within the scientists' project of using NIBS and NIBS-EEG to causally link brain processes to visually attentive behavior.[3]

NIBS, EEG, and Visual Attention

NIBS are a set of different technologies that stimulate the brain at different levels. Neuroscientists use NIBS to study the neurophysiology underlying human cognition. In the present case, they aim to establish a causal relation between neurophysiological activity and our ability to detect visual stimuli. Visual attention is typically measured using an eye-tracking device. During experimental trials, participants are asked to fixate on a red cross that appears at different places on a screen. As experiments typically involve more than one participant, the relation between NIBS and visual attention is described in terms of the average of the statistical differences within a group of participants. Hence, observing visual attention requires the translation of the result of the stimulation into a graph that visualizes the average behavioral performance of the participants.

Specific for NIBS technologies is that these allow for altering neurophysiological activity and that they are assumed to induce behavioral change. Depending on the location and intensity of the stimulation, the researchers expect that the participant's ability to fixate on the red cross will increase or decrease. The effect of NIBS is conceptualized in terms of the statistical difference between the participant's behavioral performance without stimulation and the behavioral performance during stimulation. Actual stimulation is often compared with a so-called *sham* condition, in which researchers pretend to stimulate the participant's brain. A comparison between the sham condition and the actual stimulation serves to filter out the behavioral changes that are not caused by the induced stimulation, but by the unusual circumstances in which experimental trials take place.

The neurophysiology underlying behavioral change cannot be observed using NIBS. Observing neurophysiological changes requires one to use NIBS in combination with imaging technologies such as EEG and fMRI. Only in this way researchers can detect the neurophysiological patterns that correlate with the behavioral changes occurring after stimulation. The successful integration of EEG and NIBS allows researchers to infer that the neurophysiological changes observed are actually caused by the NIBS technology, instead of being an effect of other environmental stimuli.

Constituting Visual Attention through NIBS

The causal reasoning instantiated by NIBS can be understood as follows: a stimulation technology (NIBS) causes behavioral change (BC) (see Figure 1). By stimulating the brain at a specific location at a specific frequency, researchers can test hypotheses on how stimulation influences behavioral performance. For example, stimulating a specific brain area might increase or decrease the participant's ability to fixate on a red cross that is shown on a screen. In this way, visual attention becomes present as an object that can be manipulated by the researcher, such that a causal relationship between the stimulation and the behavioral change can be established.

One of the most important problems that the researchers face is how visual attention can appear as an object that can be causally reasoned about. This requires the careful construction of causality within a specific experimental set-up. Researchers are very much aware of their own acts of construction, which makes them constantly question the reality of their own constructions. 'Too much causality' is often interpreted as an indication of a 'lack of reality'. Thus, creating visual attention in terms of causality requires the management of two potentially conflicting normative ideals that researchers hold each other accountable for: the norm of 'causality', and the norm of 'reality' (i.e. the extent to which experimental results can be extrapolated to the world beyond the laboratory). In our analysis, we show how this problem develops in relation to the technologies used, and how it is managed in the interactions between scientists. Doing so, we highlight that the constitution of visual attention is the product of how neuroscientists manage the tension between

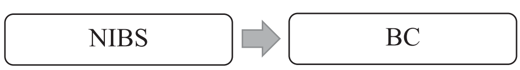

Figure 1. Causal Reasoning in NIBS Practices

normative conceptions of causality and reality. Contrary to a traditional take on science as a project that cumulatively approaches the truth about a fixed object in a stable reality, the reality of visual attention is continuously (re-)established in the negotiation between the norms of 'causality' and 'reality'.

Consider the following fragment of a conversation between Mike, Pete, Mary, and Suzy that illustrates the pattern. Suzy has just proposed a new experimental framework for studying visual attention that would be more in accordance with reality (i.e. more 'ecologically valid' (line 28)). For that purpose, Suzy proposes to integrate 'distractors' into the experimental design:

Excerpt 1:

1	Mike:	m yeah but [if=
2	Mary:	[yeah
3	Mike:	=all it means adding so::me (.) random (0.5) pictures
4		on both sides of the visual field (.) and the
5		(creations) still as they would were
6	Pete:	I- I- I think that those paradigms are quite
7		difficu::lt in terms of interpretation (.) becau::se
8		you never know whether you have an effect on the target
9		or the distractor that leads to certain behavioral
10		change (.)
		(16 lines omitted)
27	Pete:	yea-yeah emmhe I mean distractors are interesting
28		because the-they are ecologically valid right? They
29		are distractors over time an- an- an- suppressing
30		something that's not the::re is also a bit of a funny
31		thing [right?=
32	Suzy:	[yeah
33	Pete:	so I completely get where you're coming from (0.5)
34		it's just experimentally speaki::ng adding this makes
35		it a less well-controlled design

The proposal to integrate distractors is positively picked up upon by Mike in lines 3–5, who treats it as a minor adjustment to the existing experimental set-up, namely as only involving the addition of 'some random pictures' (line 3). Pete, however, treats these distractors in an entirely different way, when arguing that their inclusion would make the experimental set-up 'quite difficult in terms of interpretation' (lines 6–7), because the source of the behavioral change can no longer be detected (lines 8–10). That is, adding distractors complicates the 'NIBS → BC' logic embodied in NIBS technologies. What Mike considers to be 'some random pictures', is treated by Pete as seriously undermining the normative ideal of constructing visual attention in terms of causality. This requires a degree of precision that Pete argues to be incompatible with Suzy's proposed framework.

Pete agrees with Suzy that distractors would make the experiment 'ecologically valid' (line 28) because in real-life people continuously suppress the presence of irrelevant yet potentially distractive stimuli (lines 29–30). However, adding distractions also make the experimental set-up less well controlled (lines 34–35), which makes it no longer possible to interpret the experimental outcomes in terms of the causal relation between NIBS and BC. The experimental set-up must follow the logic instantiated by NIBS, which constitutes a norm of causality to which scientists orient in the construction of their object of research. This norm is weighed against the norm of reality in a particular way: making the experiment more ecologically valid is not treated as an option, because it is treated as conflicting with the scientists' capability to understand their experiment in causal terms. This implies that in the constitution of visual attention, neuroscientists hold each other normatively accountable for maintaining the causal structure of the experimental set-up, and they do so at the expense of its 'realness': the extent to which experimental results can be extrapolated to conditions outside of the laboratory.

Our analysis thus suggests that the norm of causality competes with normative conceptions of the reality of a constructed object in terms of its ecological validity. This indicates that when the constitution of visual attention is mediated by NIBS, (a) visual attention can be considered as the interactional outcome of how the tension between 'reality' and 'causality' is managed (i.e. as how researchers hold each other accountable in practice for these two potentially conflicting norms), (b) that the norm of causality remains unproblematized and is not reflected upon, and (c) that the tension between the two norms is treated as a tension between the causality of the experimental results obtained within the laboratory and the 'real' world *outside* of the laboratory.

Combining NIBS and EEG: Complicating Causality

NIBS technologies constitute visual attention in a specific way because they embody the logic of a causal relationship between brain stimulation and behavioral change (Figure 2). When combining NIBS with *Electroencephalography* (EEG), the construction of visual attention becomes increasingly complex. Schematically, an element is added to the causal reasoning process that also accounts for neurophysiological change: NIBS causes neurophysiological change (NPC) that in turn causes behavioral change (BC) (Figure 2). In order to make observations of neurophysiological change possible, a combination of NIBS with a brain imaging technology is required. In our case the researchers chose to combine NIBS with EEG. The combination of these technologies requires researchers to demonstrate a more complex causal relationship between brain stimulation and neurophysiological interactions.

In the group of researchers under study, EEG is combined with a specific form of NIBS: *Transcranial Alternate Current Stimulation* (TACS). TACS allows for the direct stimulation of oscillatory brain activity (Herrmann *et al.*, 2016). Oscillations can be defined in terms of frequency bands and occur constantly without the presence of experimental stimuli. It is assumed that these different

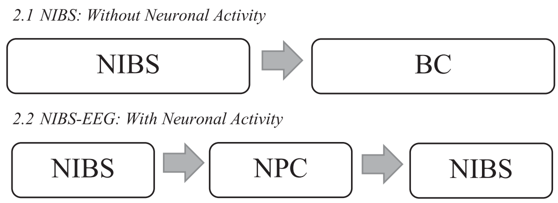

Figure 2. Causal Reasoning in NIBS-EEG Practices.

frequency-bands correspond to specific cognitive processes (e.g. Ward, 2003). The stimulation of a specific frequency-band through TACS therefore opens the possibility to establish a causal link between oscillations and specific cognitive processes.

Combining EEG and TACS constitutes a different causal logic because now a *causal relation* between TACS, the neurophysiological change corresponding to the stimulation, and the corresponding behavioral change has to be established. The combination of EEG and TACS gives rise to the need to understand brain stimulation in terms of visualizations of the underlying neurophysiology, rather than in terms of the directly visible behavioral consequences. Also, a task stimulus can no longer just be understood as producing this or that neurophysiological response that can be measured by EEG, as it has to understand this response precisely to the extent that it is caused by TACS. Not only should it become possible to observe the NPC occurring during the experiment, but the NPC must be interpreted as directly caused by TACS. As a consequence, causality can no longer be thought of as an interaction between two components, but should be understood as distributed through an increasingly complex chain of different elements.

Constituting Visual Attention Through TACS-EEG: Reality and Causality

The novel way in which visual attention is constituted through TACS-EEG becomes clearly visible when the researchers try to observe relevant neurophysiological activity and link it to the induced stimulation. This process of observation already starts before a participant receives brain stimulation. Before applying TACS, the relevant oscillatory frequency band of the participant needs to be determined because the breadth of frequency bands varies among individuals. For that purpose, participants are presented with a cognitive task (say, following a red dot on a screen), and then it is analyzed, using EEG, which activity in a specific frequency band corresponds with the behavior of the participant. Consider the following conversation in which Pete and Suzy try to determine the breadth of a frequency band:

Excerpt 2:

Pete:	I am seeing to your peak
Suzy:	yeah and I mean it' s like two hertz broad (.) they sa:y
	[hhh
Pete:	[huh yeah yeah
Suzy:	=it it' s two hertz but yeah [eh
Pete:	[eh eh it' s certainly not
	two hertz broa::d [<u>right</u>=
Suzy:	[mmm
Pete:	=because that' s too nice a number to be true::
Suzy:	yea yea yeah it' s too nice=

In line 1, Pete reacts to a graph showed by Suzy, in which he identifies a peak that indicates the breadth of the frequency band of a participant. Suzy responds by specifying the exact breadth when stating that it is 'like 2 hertz broad' (line 2), corresponding to what 'they say' (line 2). Because '2 hertz broad' is treated by Pete as an unreliable outcome (it is 'too nice a number be true' (line 9)), we take it to refer to the average in breadth across participants in general. Pete's immediate rejection of the peak being 2 hertz broad, shows that when determining individual frequency bands, researchers do not rely on external theoretical standards, but take into account that, in practice, measurements do not coincide with theoretical expectations. Contrary to the 'beauty' of theoretical generalizations, individual electrophysiological activity is 'messy'. Accordingly, the norm of 'reality' introduces an expectation that the experimental results should have a certain level of 'messiness', which in turn functions as a reason to question the adequacy of statistical analyses. The criteria of 'messiness' and 'beauty' thus co-determine the (in)adequacy of experimental results, and create certain normative expectations about the reality of the observed breadth of an individual frequency band.

Identifying an individual frequency band requires the *correlation* of neurophysiological activity and behavioral performance. When combining TACS and EEG, it has to be made sure that oscillatory change can be understood as *causally* produced by TACS, that is, not dependent on other variables. This requires a move beyond the correlational logic of EEG, which cannot rule out that a change in oscillatory activity is effected by something else than the induced stimulation. Furthermore, visual attention is no longer understood as the causal relation between TACS and BC, but as the more complex causal relation between TACS, NPC and BC (Figure 2). As we will show, the integration of NPC is not treated as a technical problem but makes researchers orient to the norm of causality such that it narrows down the way in which visual attention can be understood. That is, the reality of visual attention is causally dependent on specific oscillatory patterns as shaped by the combination between TACS and EEG. Consider the following conversation between Mike, Pete, Mary, and Andrew:

Excerpt 3:

Mike: was there anything [that you guys have seen or not
Mary: [e::::hm no I don't think that it
goes that fa:::r (.) huhu so:: it was really.hh and I-
I-I think even so what [colleague] said and I see the
same that even (.) between the different subjects for
one subject.hh the dorsal attention network is more
linked toward you kn- mmhmmh is more linked to five
hertz and for the other its more ten hertz [a::nd you
know so th-the
Pete: [muh he he
Mary: [its <u>really</u>
so we are with with the [the
Andrew: [is it just noise or is it more
than noise I mean it [could be a variable yeah
Mary: [yeah th-that's the e::h good
question [.hhhh ha
Mike: [yea::h that's indeed also what I mean if we
wanna push it by scanning nine people it would be nice
if it is on the basis of (0.5) some let's say educated
(.) guess that it works
(0.3)
Mary: yea::h
Mike: that something works huhu
Andrew: that TACS does anything (.) in the brain <u>that</u> would be
nice

When discussing the outcome of the TACS-EEG experiment, Mike asks whether the effects of TACS can be 'seen'. Mary responds that she is not sure yet because the analysis did not go 'that far' (lines 2–3), i.e. her analysis was unable to determine whether or not the oscillatory change could be causally linked to the TACS. There is too much difference between individual participants to determine whether the oscillatory change is caused by TACS (lines 5–9). This temporal understanding of seeing as a process over time instead of an immediate act indicates that whether or not an object can be observed is dependent on how it is constituted. The norms of causality and reality are constitutive of both the act of seeing and the construction of the seen. This is reflected in Andrew's question whether some kind of systematics can be detected that accounts for the differences (lines 13–14). The seeing of visual attention is dependent on the extent to which it can be thought of as causally produced by the TACS. Because no definite answer can be given to Andrew's questions, Mike says that he is at this point unsure whether '<u>something</u> works' (lines 19–20, 23), i.e. whether the individual neurophysiological differences can be causally explained in terms of the TACS stimulation.

The conversation ends with Mike displaying an insecurity if the TACS has stimulated the brain at all (line 23). This latter statement can only be meaningfully interpreted when the behavioral change is not only to be understood in terms of the TACS, but also in terms of the underlying neurophysiology.

Using the original NIBS logic, it would have been clear that the behavioral change is caused by TACS. Using TACS-EEG, establishing a relation between TACS and behavioral change is to understand the effect of TACS, but that understanding needs to be complemented with an account of the relation between TACS and the neurophysiology. TACS-EEG research complicates the norm of causality which must now be understood as the measurable causal relation between NIBS, NPC, and BC. Because of this change, it becomes possible to interpret the behavioral change caused by TACS as not necessarily 'doing anything in the brain' (lines 24–25).

This excerpts shows that the reality of visual attention is dependent on how the normative tension between 'reality' and 'causality' is managed in a particular way in the context of TACS-EEG. The new ways in which the relation between the researchers, and the relation between the researchers and the technologies they use marks a crucial difference with experiments in which only NIBS is used: whereas in these cases, the norm of 'reality' is oriented to in terms of whether or not results can be extrapolated beyond the laboratory, in the case of TACS-EEG, the reality of the causal link between the induced stimulation and the behavioral change becomes itself subject of dispute.

Because the reality of the causal relation between stimulation and behavioral change is problematized, it is no longer straightforwardly clear how NIBS, NPC, and BC link together. However, regardless of this newly introduced uncertainty, researchers remain oriented to both a norm of causality and a norm of reality in TACS-EEG research. Consider the following interaction between Suzy and Pete:

Excerpt 4:

```
Pete:   them and try to applic- apply them somehow hhh I am
        totally not convinced[ laughter]
Suzy:                        [ no?
Pete:   naaa nooo it- its its its a conflict of of research
        styles its its eeh (2.0) huhuhuh
Suzy:   tell me more about it?
Pete:   no::: its its just I would always start with a proper
        EEG[ experiment=
Suzy:      [ mhmm
Pete:   =we have behavi[ orally=
Suzy:                  [ yea yea
Pete:   =(0.3) things that can relate to physiological measures
        and and you kno:::w and then you have (.) a
        correlation::: (0.3) of two things and then you can (.)
        move on to causality with brain stimulation thats just
        how I feel about it
```

Pete indicates that he is uncertain about the approach taken in the laboratory when doing TACS-EEG research (line 2). When saying that there is a 'conflict of research styles' (lines 4–5), he contrasts the work in the lab with an approach that would 'start with a proper EEG-experiment' (lines 7–8). Such an experiment would establish a correlation between behavior and physiology, from which he asserts that causality can be inferred; at least that is how Pete 'feel[s] about it' (line 16). The use of words that have a subjective connotation such as 'research styles' and 'how I feel about it', indicates that his own approach does not provide a, for participants, objective way to construct visual attention through the use of TACS-EEG. The constitution of visual attention in terms of TACS-EEG is dependent on the individual style of the researcher, and is not treated as an 'objective' solution that determines whether the neurophysiological change is caused by TACS—as would be the case when only NIBS was used to investigate the human brain. Although Pete suggests to 'start with a proper EEG experiment' (lines 7–8)—indicating a clear starting-point—he does not motivate this idea except for that it would be the consequence of his preferred style of research.

The combination of intervening with NIBS, and imaging with EEG, requires the integration of the causal reasoning embodied in NIBS, and the correlational reasoning embodied in EEG. In NIBS research, the construction of visual attention can best be understood as managing the tension between 'causality' and 'reality', in which causality within the scientific experiment is treated as unproblematically realized through NIBS. However, with the introduction of EEG, 'seeing' visual attention is being treated as problematic in this context, and the researchers cannot easily design a causal understanding of behavioral change in terms of the relation between the induced stimulation and neurophysiological change.

In sum, the constitution of visual attention when investigated through TACS-EEG reintroduces a norm of causality that appears as more complex than in the case of NIBS because a new variable—neurophysiological change—needs to be integrated. Through this complexity, the norm of causality *within* the scientific experiment can no longer be unproblematically applied, but becomes itself subject of dispute. The 'reality' of causality is treated as being relative to contingent norms such as personal research styles that 'allow to move from correlation to causality' (excerpt 4, 13–14). This indicates that how causality is made normatively relevant in the constitution of visual attention is mediated by the specific technologies involved (i.e. different in the case of NIBS than in the case of TACS-EEG).

Conclusion and Discussion

Our analysis answers the question how the scientific object 'visual attention' is constituted in the interactions between scientists that collectively relate to NIBS and the combination of NIBS and EEG. We revealed the presence of a dominant orientation towards a cause–effect model of the relationship between brain and behavior, and show how that orientation is taken for granted in the scientists' research routine. In the context of NIBS, we argued

(a) that constituting visual attention can be seen as the interactional outcome of a tension between a messy and thus (more) real world and 'causality', (b) that the norm of causality remains unproblematized throughout, and (c) that the 'tension between the two norms is treated as a tension between the causality of the experimental results obtained within the laboratory and the 'real' world *outside* of the laboratory.

When NIBS is combined with EEG, the norm of 'reality' takes a different shape, because now the reality of the causality obtained *within* scientific experiments is disputed, such that the norm of causality can no longer be unproblematically applied in the context of NIBS-EEG. When brain activity is made visually available, the researchers cannot straightforwardly assume a causal relationship between the induced stimulation and the observed behavioral change. This, however, does not make researchers refrain from normatively orienting to causality, but rather safeguard the constitution of visual attention in causal terms by orienting to contingent, subjective norms such as individual research styles (cf. Gilbert and Mulkay, 1984, p. 57). This suggests (a) that how researchers orient to the norms of causality and reality during the constitution of visual attention is mediated within the relations between scientists and technologies; and (b) that 'causality' and 'reality' do not function as explicit norms, but as implicit criteria, for which participants hold each other accountable, thus actively using them for the constitution of visual attention as a neuroscientific object.

Through a combination of postphenomenology and CA, we brought to the surface the interactions through which cognitive neuroscientists attempt to accomplish translating an observed phenomenon into a scientific object. Furthermore, we showed that such attempts are mediated by the different technologies used, such that visual attention is constituted differently in the case of NIBS, than in the case of NIBS-EEG.

We have drawn on postphenomenology to study how scientific objects come into being within constellations of technologies and scientists. The postphenomenologist Don Ihde (2009, p. 64) has argued that technologies always partly determine (i.e. mediate) how scientists interpret the reality that they are studying, and has suggested to understand scientific practices as *material hermeneutic* practices. We added to this work by using CA to reveal the interpretative processes through which technological mediations are appropriated (cf. Verbeek, 2016), thus showing *how* a phenomenon made visible by material technologies is translated into an *object of research*, namely, visual attention. The discursive interactions that scientists engage in—and that we have studied by using CA—can therefore never be cut loose from how the world is always already partly interpreted for them by the technologies they use. Our analysis can therefore be considered a detailed analysis of the coming into being of a specific constellation of humans and technologies within which scientific objects such as visual attention attain a specific reality.

Understanding technologies as mediating how visual attention is constituted might remind of the common idea in STS that technologies have preferred plans of action inscribed in them (e.g. Akrich, 1992). Indeed, when NIBS-EEG is used, the researchers necessarily need to construct experimental set-ups in which brain activity can be measured and imaged. However, as our analysis shows, the plans of action that technologies prescribe do not determine how visual attention is constituted, as the norms that scientists orient to are themselves not inscribed in the used technology. This is exemplified by how 'visual attention' is constituted by how scientists manage a tension between the potentially *conflicting* norms of 'reality' and 'causality', a tension that is itself neither inscribed into NIBS nor into NIBS-EEG. By studying *in actu* how researchers hold each other accountable in terms of this tension, we have shown how the constitution of visual attention takes place within a specific normative orientation that is shaped by the technologies used.

In an ethnomethodological study on scientists researching fish vision, Roth has shown how the existence of the objects that fish scientists investigate are mediated by microscopic images and are stabilized through actions that can only retrospectively be understood by the scientists. He argues that 'radical uncertainty [about what is seen] exists prior to the moments when things become the witnessable objects that can be talked about' (2009, p. 316). Similarly, our analysis shows that no action plan is available determining beforehand how 'visual attention' can be turned into an object that can be seen. However, during the constitution of visual attention, the witnessability of brain activity and the possibility to talk about it does not necessarily translate it into an object of research that fits the purposes of the general project that laboratory members are immersed in. Rather, uncertainty remains to persist during the interactional discursive practices within which visual attention is constituted. That researchers continuously have to manage the normative tension between causality and reality and hold each other accountable for it is illustrative of this uncertainty. This is for example visible in excerpt 3, which exemplifies that what can be seen does not have to coincide with the object desired to be observed (i.e. visual attention).

What are the consequences of this perspective for the way the brain and mind are investigated in big science projects such as the Decade of the Brain and the Decade of the Mind? Can 'a mathematical and predictive framework of how all elements [of the mind] fit together and act as a whole to give rise to intelligence and consciousness' (Koch *et al.*, 2015, p. 39) be developed? Critical approaches to the neurosciences have argued that neuroscientific research cannot be unproblematically used to solve societal problems (e.g. Dumit, 2004). In their call for a Critical Neuroscience, Choudhury and Slaby call for critical engagement with neuroscientific research, and argue that research on the impact and practices of neuroscientists should help to answer the question 'what kinds of ideas, hopes, methods, and institutions come together to produce what will count as facts about the brain?' (2012, p. 4). By making explicit the role of the epistemic norms of causality and reality in the constitution of visual attention, we suggest that a specific normative framework constituting what counts as cause–effect relationship comes into being as a consequence of how technological mediations are appropriated.

Our analysis suggests that the nowadays popular understanding of the human brain as an autonomous agent as largely determining human behavior may not come as a surprise. Even though neuroscientists themselves voice discontent about this portrayal of their work (Allgaier *et al.* 2013, p. 426), the presumed causal efficacy of the brain on human behavior is normatively oriented to even at the level of fundamental research on visual attention. In addition to this, we have shown in this paper that, in neuroscientific practice, the causal efficacy of the brain on human behavior cannot be straightforwardly assumed, but is instead contingent on how the tension between the norms of 'causality' and 'reality' is managed. Accordingly, the causal efficacy of the brain on human behavior does not reflect an existing state of affairs external to the group of scientists, but is normatively accomplished during the processes in which neuroscientists appropriate technological mediations.

Notes

1. Previous empirical postphenomenological studies on scientific imaging have nicely shown how technologies mediate perception in scientific practice in the context of microscopy in a cytology laboratory (Forss, 2012), and in particle physics (Hasse, 2008). In the present paper, the focus is not primarily on scientific *imaging*, and hence less on how visualizations of scientific phenomena become perceptually available. Accordingly, the concept of 'appropriation' is used precisely to understand how technologies mediate the constitution of scientific objects beyond the perceptual – although it does not at all aim to deny the fundamental importance of perceptual observation in scientific practices. To reveal the subtleties of how technological mediations are appropriated *in actu* requires to engage closely with the flow of action in which scientific practice takes place. This flow of action cannot be captured by using empirical methodologies such as interviewing techniques or participant observation (e.g., Aagaard, 2015; Hasse, 2008), but *can*—so we argue—be fruitfully approached from the perspective of CA. For a more detailed discussion about postphenomenology and its relation to different empirical research methodologies, see Aagaard *et al.* (2018).
2. ELAN is developed by the Max Planck Institute for Psycholinguistics, The Language Archive, Nijmegen, The Netherlands (url: http://tla.mpi.nl/tools/tla-tools/elan/). For an explanation of ELAN, see Wittenburg et al. (2006).
3. Further extracts of the empirical material are available upon request.

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Appendix 1. Transcription symbols according to the Jefferson (2004) transcription system.

[ ]	indicate the start and end of overlapping speech
underliningindicates	emphasis
CAPITAL	indicate a section of speech noticeably louder than that surrounding it
he he	indicates voiced laughter
.hh	indicates in-breath
(1.1)	indicates pauses in seconds
(.)	indicates micro-pause, too short to measure
:	colons indicate (degree of) elongation of the prior sound
?	indicates question