Strong Neurophilosophy and the Matter of Bat Consciousness: A case study[1]

Abstract:

In "What is it like to be boring and myopic?" Kathleen Akins offers an interesting, empirically driven, argument for thinking that there is nothing that it is like to be a bat. She suggests that bats are "boring" in the sense that they are governed by behavioral scripts and simple, non-representational, control loops, and are best characterized as biological automatons. Her approach has been well received by philosophers sympathetic to empirically informed philosophy of mind. But, despite its influence, her work has not met with any critical appraisal.

It is argued that a reconsideration of the empirical results shows that bats are not boring automatons, driven by short input-output loops, instincts, and reflexes. Grounds are provided for thinking that bats satisfy a range of philosophically and scientifically interesting elaborations of the general idea that consciousness is best understood in terms of representational functions. A more complete examination of bat sensory capabilities suggests there is something that it is like after all.

The discussion of bats is also used to develop an objection to strongly neurophilosophical approaches to animal consciousness.

I. INTRODUCTION

For a long time, the question "What is it like to be a bat?" has framed perplexity about the nature of consciousness. Although a starting point for a metaphysical inquiry, Nagel's (1974/1998) question also raises epistemological concerns, including how we can know whether a non-human is conscious, and if so, what that is like. Certainly bats can perceive, be awake, alert, and responsive to their surroundings. What is less obvious is whether those states of awareness have a distinctive phenomenal feel, that is, whether there is something that it is like for bats to undergo them, and whether bats have what Nagel calls a "subjective point of view." Though many, including Nagel, take this for granted, one source of skepticism deserving more discussion is Akins (1993, 1996) who takes up what can be called a "neurophilosophical" approach.

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Neurophilosophy is not a crisply defined tradition, but a loose affiliation of aims, methods, and programs, pulled together by a shared commitment to philosophizing that is empirically informed. Neurophilosophy contends that traditional philosophical issues, including the nature and explanation of consciousness, are best investigated through the methods and results of the brain sciences (Brook and Mandik, 2007). Taking this as her starting point, Akins delves into the literature on bat echolocation. Akins argues that discoveries in neuroscience may have startling implications, including that "[t]he bat...may fail to have a point of view...this is to say that the bat lacks certain representational capacities, a conception of the world as objective particulars" (Akins 1993, p.155, 1996, pp.357-8 n.2). Akins' provocative argument for skepticism about bat consciousness, interesting in its own right, offers an opportunity to reconsider the prospects for empirically informed philosophy of mind when it comes to puzzlement about animal consciousness.

Many philosophers, suspicious of aprioristic reasoning, have embraced a neurophilosophical outlook (for overviews see and Brook and Mandik, 2007 and Bickle *et al.*, 2012). Several explicitly endorse Akins' empirical approach to animal minds, including Dahlbom (1993), Dennett (1993, 1998), Brook and Mandik (2007), Bickle *et al.* (2012) and Macpherson (2011). Macpherson (p.29, n.44), for instance, applauds Akins' "informed speculation on the representational and phenomenal nature of the bat's experience," while Bickle finds her use of physiological results "pertinent to Nagel's question" about bat subjectivity. Dahlbom, likewise, remarks that Akins draws attention to "research results which bring into sharper focus philosophical worries about subjectivity and the nature of beliefs" (Dahlbom 1993, p.7). Brook and Mandik (2007, p.18) include her among philosophers who want to "throw science at [the problem of consciousness]…to produce the kind of account that is supposed to be

impossible." Meanwhile her work leads Dennett to anticipate profound revisions for our views on the mental character of animals (Dennett 1998, p.348), starting with the possibility that "There may not be anything at all that it is like to be a bat" (Dennett 1993, p.228).

Contrary to this enthusiasm, I find Akins' case for skepticism about bats wanting, yet still worth engaging for several reasons. There is the novelty of her view and its grounding in the empirical methods that influence much recent philosophy of mind, the importance of meeting challenges posed to comfortable orthodoxies, and the fact that, despite being widely cited and taught, her articles on bats have not been met by any sustained philosophical critique.[2] I also find her work instructive as a test case for one version of the neurophilosophical outlook. Neurophilosophers differ somewhat over how the relationship between science and philosophy ought to go. Some contend only that philosophizing needs to be constrained by, or perhaps explicitly appeal to, empirical findings. Others go further, predicting that the resolution or transformation of traditional philosophical problems will follow from close attention to empirical inquiry. This discussion will consider how Akins' investigation of bat consciousness might support these agendas.

II. TWO VARIETIES OF NEUROPHILOSOPHY

Having justified this topic, my aims can now be stated. First, regarding bats, I will argue that Akins' makes an unpersuasive argument for skepticism on the matter as to whether there is something that it is like for them. Bats, as with other mammals, are almost certainly conscious. Second, my response to Akins' will lead to some general reflections on the investigation of animal consciousness from scientific and philosophical perspectives. Although there is a sense

[2] In addition to their intrinsic interest, our views on animal consciousness have obvious ethical ramifications.

in which her approach is valuable, there is room for doubting that puzzlement about consciousness is going to be satisfied, transformed, or replaced, by empirical study.

To help explore this thought, I suggest a distinction between strong and weak neurophilosophy. Strong neurophilosophy (SN) is defined in terms of its epistemological method and offers a break from philosophizing based on introspection and intuition. SN maintains that the aposteriori methods of normal science (especially ethology and neurophysiology) offer a transformative approach to traditional philosophical questions about animal minds, such as whether and why they are conscious, how we can know it, and what it is like (if anything). The idea of transforming questions is left somewhat imprecise, though it is often explained in terms of conceptual change. Nagel's (1974/1998) example of how conceptual innovation overcomes pre-scientific bafflement at the notion that matter is really energy anticipates this suggestion. Likewise, perhaps a question like "Are bats conscious?" is intractable pending suitable conceptual advancements driven by discoveries in neuroscience which would somehow alter our comprehension. SN is perhaps given its most robust articulation by Churchland (1986), but even where it is not overtly declared, it serves as a structuring background for attitudes, agendas, and practices for philosophers such as Akins.

Meanwhile, weak neurophilosophy (WN) makes only the mild contention that normal science can be used to discover the information processing functions responsible for conscious experience. WN is along the lines of what Nagel calls "objective phenomenology" and is an uncontroversial position, even compatible with philosophical worries about the metaphysics of consciousness and the explanatory gap. WN consists in the investigation of what Akins (1993, p.139) calls "negative constraints" and "positive characterizations." These fall under the purview of empirical study. Negative constraints are structural limitations of nervous systems

rendering them insensitive to potential stimuli, and which accordingly place constraints on the character of a subject's phenomenal experience, e.g. that monkeys don't detect infrared light (Akins 1993, p.125) is a negative constraint on their conscious experience. We can, in short, scientifically know about deficits in conscious experience by knowing what information an organism lacks. We can do this by examining its sensory equipment, its environment, ecological needs, and the kinds of physical signals available to it. The same kinds of facts can also figure into positive characterizations of phenomenal experience, e.g. knowing that a subject can distinguish red from green suggests corresponding differences in her color experience. Clearly, objective phenomenology doesn't support or even presuppose SN. In fact, neither view has much to offer philosophy, since SN is probably false and WN borders on triviality.

The reminder of this section makes four points. First, the reason why the choice between SN and WN is philosophically barren is explained. Second, a sharper sense of SN, and who is committed to it, is provided. Third, neurophilosophical agendas that are not being targeted by the present essay are acknowledged. Fourth, the rationale for drawing general conclusions about strong neurophilosophy from this single case study is given.

SN is philosophically interesting, and what many seem to have in mind when neurophilosophy is advertised as an alternative to traditional philosophy of mind. However, SN is most likely false, or at least not warranted at this time. Meanwhile, although WN is true, it is obviously so, and, although relevant and important within neuroscience, philosophically it is uncontroversial. Although this does not exhaust the prospects for neurophilosophy, this result would be a disappointment for its most enthusiastic advocates. Although SN and WN are compatible, and it is not uncommon for empirically informed philosophy of mind to endorse (and sometimes conflate) them, there is a difficulty. On the one hand, WN is easy to establish as

an investigative framework—after all, it amounts to little more than the claim that, as Akins puts it "science has something to say" (1993, p.127) about information processing functions. Who doubts that? It is platitudinous to say such things as that one needs eyes to see, and that discovering how perceptual systems work is best left to scientific experts. So, WN is trivial in the sense that it is nearly universally accepted (even by dualists), since it presupposes little more than the supervenience of the mental on the physical. Meanwhile, SN says more, but is much harder to justify.

One type of SN draws on a Quinean rationale about the weakness of interdisciplinary boundaries and the "co-evolution" of theories and their descriptive terms. Absent no clear division of labor between scientific and philosophical concerns, "macro and micro-level theories co-evolve through time as each provides tests, problems, and ideas for the other" (Churchland 2005, p.286). Churchland offers precedents from the history of science purporting to show that "the meanings of words in the descriptions undergo a parallel semantic evolution…For this is the period when folk ideas are gradually replaced" sometimes leading to radical semantic change, as with terms like "fire," "heat," and "genes," and sometimes even outright elimination, as in "caloric" or "phlogiston." Whether leading to reduction, revision, or, outright elimination, "[t]his is the period when the ostensibly obvious gets wrecked on the shoals of scientific discovery" (p.286). So perhaps these kinds of examples should set up expectations about dramatic changes to folk ideas when it comes to animal minds as well.

This is not to say that only those allied to Quine, or committed to the elimination of folk psychology, count as strong neurophilosophers. That is just a striking example. Something broader is intended, though absolute precision is difficult. Diverse philosophers draw on empirical science to inform their work, though this can be compatible with WN. There is

probably no single diagnostic, such as one's attitude about absent and inverted qualia. Somebody could reject the explanatory gap, but on apriori grounds, or, accept it, but find neuroscience highly relevant to other philosophical concerns. There is a profusion of decision points and pertinent issues (e.g. is science needed to solve all philosophical problems, or just some of them; which ones?). It can also be noted that the WN/SN distinction is not meant to be exhaustive. But then what is sufficient for SN? I think what it comes down to is the belief that throwing science at the problem will stimulate a certain kind of progress. The basis of SN is some form of naturalized epistemology (possibly non-Quinean), including a rejection of apriori intuition, specifically when it comes to understanding the mind and, especially, consciousness. This too is ambiguous, in light of the fact that progress could be understood as scientific, but not philosophical, the reverse, or one could even deny a meaningful distinction between empirical and philosophical advancement. SN is probably best interpreted in terms of the second or last of these; the first would be only WN: throwing science at a problem in order to get scientific progress.

Besides the Churchland's (especially Patricia Churchland's 1983, 1987), a number of empirically oriented philosophers seem to be advocates of neurophilosophy in the strong sense arguably including, Bechtel, Bickle, Brook, Gylmour, Dennett, Lloyd, Mandik, Ross and Thagard, to name just a few.[3] Bickle and Mandik (2012), for instance, write of the "encroachment" on the philosophy of consciousness by scientific theorizing and cite Akins (1993) as an example. Elsewhere, Bickle (2005: 293) elaborates on his outlook, dismissing "analytic methodology and/or metaphysics" as "fruitless" since it leads only to "clashes of

[3] A certain degree of haziness might be unavoidable and there are probably many penumbral cases. Part of the difficulty might be that science-friendly philosophers are not always explicit about precisely how science sits within their epistemology of mind. Perhaps further work could help clarify what is at stake and where people stand. The present work itself, as one referee observed, is arguably some kind of neurophilosophy.

intuition." He bluntly advises "taking up philosophical issues that can resonate with scientists…and setting the rest of philosophy aside." Bickle's quietism does not seek to solve traditional problems on their own terms, but instead predicts a transformation in method and agenda "that makes scientific research applicable." Mandik, likewise, is skeptical about introspection and intuition as a source of knowledge about phenomenal character. If it is to be known at all, which he doubts, the subjective character of consciousness is "beholden to empirical considerations" (Mandik 2009, p.616) in the spirit of Quinean naturalized philosophy (Mandik 2007, p.418).

As I say, SN can be understood in different ways, depending on whether neuroscience is to answer, reform, or perhaps eliminate folk conceptions. Whether science *ousts* or merely *naturalizes* traditional philosophical questions about consciousness, mirrors a familiar distinction in naturalistic epistemology. One view, represented by Quineans is that traditional questions about the nature of knowledge and justification are sterile, and the only questions worth asking are about the processes responsible for belief formation. Another, attributable to Goldman, preserves folk conceptions, in a sense, by transforming normative concepts into ones that can be empirically investigated, such as by construing justification as reliability. A similar split occurs between neurophilosophers. Some endorse Churchland's prediction that folk conceptions will eventually be discarded. This echoes Giere's claim that naturalized epistemology will eclipse the old paradigm by way of empirical success rather than by explicit refutation (Giere, 1988). A more revisionary neurophilosophy (Gillet 1991 and Hardcastle 1997 are presumed examples) is comparable to the view Goldman (1985) develops which allows that folk conceptions get some things right, even if progress consists in turning the issue over to science. Common to all forms

of SN is the dismissal of introspection and armchair analysis as a special source of knowledge about the appearances as such.

Having sketched and given examples of the strong kind of neurophilosophy, there are two qualifications I wish to make. This is not a blanket rejection of empirically oriented philosophy of mind, but only one lifeless facet (and perhaps outright rejection comes off as too conclusive, and my criticism is better construed as a doubt or a worry). The "neuro" movement in philosophy has a broad scope and influence, encompassing a range of views beyond what I am calling the "strong program." Naturalistic outlooks have been propelled by stunning advancements in the neurosciences, and philosophers have seen fit to draw on these results in various ways: to articulate theories of mind that are empirically enriched, to re-think inter-theoretic reduction, to respond to property dualism, to offer arguments against analytic functionalism and multiple realizability, to reorient traditional debates about the nature of representation, and more. Nothing said here need be taken as criticism of these projects.

Secondly, I am not claiming strong neurophilosophy is a failure just in light of one or two papers from Akins. Earlier I suggested that her project be considered an experiment testing SN's prediction that revision or rejection of folk-conceptions is, in fact, forthcoming. Akins can be regarded as attempting to help win the standoff for the neurophilosophers by actually laying a foundation for the integration of intertheoretic discourse and subsequent semantic adjustment. This is why I have chosen to look carefully at her work as a representative case, rather than attempt a systematic review of neurophilosophy. In other words, will a close, "Churchlandish," look at the empirical results about bats either lead to a rethinking of our folk conceptions, or, perhaps show that questions about animal consciousness meet with an empirical resolution? Will throwing science at the problem help? Are there signs of progress?

III. AKINS ON BATS

The next two sections offer a critical appraisal of Akins' work on echolocation, and following that is a reflection on how her project bears on the prospects for neurophilosophy.

Akins begins by stating that she wants to avoid unpleasant "metaphysical entanglements" about dualistic qualia, subjectivity, and the explanatory gap (1993, p.128) and focus on what can be inferred from the scientific study of echolocation. At one point (p.127), however, she acknowledges she has no reply to Nagel and prefers to change the subject. As she says, she would rather "set aside the puzzlement…and take the other route" (p.127). Despite this, there is a danger of getting distracted by results that are relevant in the weak sense, and to conflate it with SN. That is, are we to understand this "other route" in terms of WN or SN? Though Akins doesn't explicitly make this distinction, presumably it would be something more like the latter: SN. Recall that WN is compatible with views such as Nagel's, and so can't lead away from them. So, presumably, a careful examination of the empirical results might point towards the integration or transformation of our folk conceptions within an emerging neuroscientific paradigm. In short, the *aim* of her empirical study is surely to be more than just an exercise in WN—which is best left to neuroethologists and physiologists, not philosophers.

Having said that, Akins' skepticism is more nuanced and tentative than it may appear from the endorsements mentioned earlier. More than once she is careful to qualify her skepticism as just a reasonable interpretation of the relevant scientific results, but in no way conclusive. Arguably, Akins is not even committed to SN. Several of her remarks indicate ambivalence, but it can at least be said that she exhibits tendencies that seem to presuppose strong neurophilosophy. Many appear to take her to be an excellent representative of the

neurophilosophical outlook, so I want to consider how her work might be contributing to the more ambitious paradigm.

In "What is it like to be boring and myopic?" (1993) Akins dispenses with a naïve "intuitive" view, associated with Dawkins (1986), in which bat echolocation is assumed to be analogous to human visual awareness, in the sense of an internal model of three-dimensional space. Instead "what the empirical data makes plausible...is that what the...bat *hears* is probably not what we *see*—not even what we see, minus little bits and pieces or with less spatial detail or with a narrowed field of view...in all likelihood it does not use its sonar system to construct representations of the objects around it [including trees, insects, and other bats]" (Akins 1993, p.147). She continues:

> Unlike our own visual perceptions...the bat's sonar experience is probably neither imagistic nor—more importantly—an experience *of* a world of objects and properties. *Hence it seems plausible that the bat may not have a point of view at all* (p.147, emphasis in original).

If bats don't represent particular three-dimensional objects then "it makes little sense" to attribute a point of view with objects and their properties as conscious contents. With there being no objects for it to perceive, there are "no objects for the bat to perceive *in a certain bat-like way*" (p.151).

Akins' skepticism is premised on a consideration about explanatory parsimony, and illustrated through a fanciful story about a "wingflapper," or neural homunculus, who is imagined to be at a control panel, flying the bat around, catching bugs, and so on. The wingflapper utilizes information supplied by various "dials" and "indicators" which display a target's suitability as a snack, its range, direction, the bat's own speed, and other matters of interest. These "instruments" correspond to actual regions in the bat's auditory cortex with specific information processing functions (Akins 1993, p.147). Of course, the wingflapper is not

seriously proposed. But, similarly, it is extravagant and unnecessary to posit conscious mental processes tokening representations of the bat's environment. This is because the "instruments" *themselves* suffice to explain batty behavior.

> [T]he story makes for a useful fiction because it makes vivid one essential point, namely just how small the gap between the bat's sonar input and its motor output might be: how little intermediary processing is required to translate (in the mathematical sense) the auditory information of the primary cortex into motor commands" (p.148).

There is no need for a supervisory, homuncular, layer of control if the wingflapper's "decisions and actions" could just as well "have been performed by a reasonably simple control system" (p.148) comprising a battery of adaptive fixed-responses, such as those accounting for the stereotyped movements observed in many species of bats. For example, perhaps one algorithm is dedicated to triggering a sharp, upward turn in response to an input indicating the presence of a large looming object (p.149). The processing for auditory-motor control utilizes scant, highly specific, inputs that are just barely sufficient to direct "rapid and stereotyped movements" (p.149). As its information processing needs are so simple, it seems unlikely any cortical region in the bat plays the role of a "wingflapper," that is, a central controller trafficking in unified representations of the environment.

Akin's argument can be summarized as follows:

Premise 1: The bat's behavior is best explained in terms of an "instrument panel" governed by a system of simple control algorithms, rather than complex, integrated, representations of objects.
Premise 2: Given that the bat's behavior is best explained in terms of an "instrument panel" governed by a system of simple control algorithms, rather than complex, integrated representations of objects, it is probably not conscious.
So, The bat is probably not conscious.

The rationale for the first premise would seem to go like this: the wingflapper notion is really a rhetorical stand-in for the hypothesis that the bat employs "complex" processes which manipulate representations in contrast with the alternative positing only "simple," non-representational, processes. Akins draws on three levels of analysis for support: behavioral,

neuronal, and neuro-computational (1993, p.149). With respect to behavior, Akins argues that bats are often inflexible "boring" automatons (p.134), as in the stereotyped "set routine" they follow when hunting (p.133). In addition, specialized neurons tuned to fire at "preferred" stimuli (p.143) are insensitive to signal properties not immediately relevant to guiding the search and pursuit of prey (pp.149-50). Finally, signal processing utilizes what information is available in tightly sequenced steps, obviating the need for "any intermediary processing…nor any of the representational capacities that would thereby be required" (p.149) beyond the "rudimentary information coding" needed to "drive motor control" (p.150). In addition, memory limitations suggest there is no integration of what little information is available (p.150). In sum, sphexish behavior, highly specified coding, and simplistic processing suggest that bats token no representations of middle-sized objects such as trees, rocks, (pp.146-7) and moths (p.151). Without a unified representation of a three-dimensional world of objects, and combined with the second premise, it is concluded that bats may not have a point of view at all.

My main reply is that the first premise is only weakly supported by the evidence. In a moment I will argue that the coding and processing are more sophisticated than Akins allows. After that I will consider how bat behavior also seems to require the positing of internal models of everyday objects and spaces. But I also have a little to say about the rationale behind the second premise and why I think it is plausible. So, in the next section I will take up the theory of consciousness (premise 2), and after that will return to an empirical critique of the first premise.

IV. EVALUATING AKINS' ARGUMENT

In order to see how Akins uses neurophysiology to draw conclusions about consciousness, it's helpful to reconsider the significance of the wingflapper. Recall that it was to be responsible for the bat's decisions and actions as "an intelligent hand on the controls" (1993, p.149). At first this consideration might seem off-topic given that consciousness or a "point of view" (p.125) is the central issue, not cognitive control. Even if bats are "boring" in the sense of being governed by tropes and stereotypical patterns, why should this tell us anything about whether or what it is like to be boring? As noted by Griffin (1992), "boring" reflexes in humans can be accompanied

by subjective consciousness (e.g. a sneeze).

To make sense of this, it seems reasonable to interpret Akins as linking intelligence and consciousness by way of a cognitivist theory. This would place Akins' within a broad tradition conceiving of conscious processes in terms of representation-processing functions. Representationalist views include first-order theories as offered by philosophers such as Dretske (1995) and Tye (1995, 2000), and, higher-order accounts offered by Rosenthal (1986), Lycan (1996), and Carruthers (2000). These philosophical theories find their empirical counterpart in the influential Global Workspace or "broadcasting" model put forward by psychologist Baars (2005). The upshot is that a plausible (though, for now, imprecise) way to interpret the linkage between "integrated" or "intermediate" representations and consciousness is this: conscious contents are those made widely available for various cognitive tasks in belief-like representations. This sort of view is attractive for various reasons that will not be considered here (cf. Tye 2000). Akins seems to agree inasmuch as phenomenal experience is assumed to depend on an "intentional agent" (1993, p.149) with (at least) first-order beliefs and desires (p.148) which make information available for rational thought, planning and action (in a rudimentary sense, appropriate for an animal). Hence, her skepticism about bat consciousness depends on the absence of global representational processes whose function is to integrate sensory information and make it available in belief-like states usable in practical reason. If there is no wingflapper, that is, the materialist equivalent of a Cartesian Theatre or Global Workspace, where the processing generates a unified representation of the world, there is nothing that could serve as a conscious subject of awareness.[4]

Akins seems to be saying that boring automatons lack first-order cognizing and, so, are not conscious. Akins elaborates somewhat (1993, p.157 n.22), taking a Strawsonian (1959) line

[4] Skepticism about bat consciousness, and indeed most animals, would seem to follow from higher-order accounts which are often assumed to imply that most, or perhaps all, non-humans are not conscious in virtue of the fact that they do not token beliefs about beliefs. Akins' view is that bats (and presumably many other animals) do not token even primitive beliefs and desires, and so fail to satisfy the more generous interpretation of global availability offered by first-order representational accounts.

that conceives of conscious representation in terms of "objective particulars." On this view, beings must be capable of (1) distinguishing between self and world (as in the difference between the bat's own movement versus that of a moth), and, (2) the ability to re-identify particular objects (a) by retaining awareness of the object even when it is not currently perceived, and, (b) by making the distinction between quantitative and qualitative identity (as in a specific moth under pursuit versus another that looks just like it).

The adequacy of these conditions is not at issue here, for even under these constraints, it is not plausible that bats are "boring" biological automatons governed by simple mechanisms and behavioral scripts. Though for Akins the "input-output "loop" of the bat, it seems, might be very short indeed" (Akins 1993, p.149), another look at the evidence suggests otherwise.

There are two points that help show why bats are not only driven by response contingencies and instincts. First, the alleged deficits in memory and integration are implausible with respect to echolocation. Secondly, this does not take into account other sense modalities, such as vision. There seems to be sufficient information available for bat-brains to construct representations of objects in their spatial environs. Both echolocating and visually mediated behavior are strongly indicative of intelligence beyond simple control loops. Bats are capable of abstract learning, and arguably have the requisite intentional states for first-order representational consciousness. This is also suggested by their navigation behavior, in which rocks, trees, fences, and hills are used as landmarks. The reminder of this section develops these points.

Consider again the matter of neuron coding in the bat's auditory cortex during prey capture. The encoding generally involves informational loss because auditory neurons "respond only to particular aspects of a complex stimulus" (Akins 1993, p.149). As this suggests that "the bat may require...little else except this kind of rudimentary information coding...Perhaps, then, the bat neither has nor needs the capacity to produce complex sonar representations" (p.150). But surely there is something wrong in the suggestion that complex representations require complex inputs at the neuronal level, seeing as simple inputs could be combined in complex ways further along the processing stream. Assuming Akins is, nevertheless, correct about this,

there is no hint as to how much specificity she thinks disqualifies a neuron from being implicated in complex representations. Neurons correlated with conscious experience in humans are often "tuned" to highly specific inputs. Neurons, after all, need to filter signals for noise. Although some are tuned for relatively complex stimuli, as in visual system neurons dedicated to detecting faces, others respond to more simple properties, such as edges, orientations, and basic forms. Indeed, many human auditory cortex neurons are also receptive to only rudimentary characteristics of sounds, such as frequency or amplitude (Kolb *et al.*, 2003). In light of this, it hardly seems to follow that the coding found in bats is inconsistent with integrated representations and consciousness.[5]

That some perceptual information is lost in the output of the bat's "control panel" hardly shows that there is no spatial representation occurring, and there is plenty of information still available for integrated representations of persisting targets. The "instruments" indicating the subtended angle of the target and the heading to intercept offer information about elevation and azimuth. As noted by Fuzessery (1986) this suffices to represent location in three-dimensional space. The distance, relative velocity, size, texture and, remarkably, internal constitution of prey are also available (Suga, 1984). Some bats, informally known as "hawkers," even use the rate at which an insect beats its wings to select their prey, and as this ability can be honed with training, it is more than a simple reflex (Bradbury and Vehrencamp 1998, p.875). Some hawkers even distinguish prey with identical wingbeat rates by attending to still other properties. Again, the point is just that the specificity of coding at the level of individual neurons is quite compatible with the construction of representations of moth-like targets, or, to be more precise, of small fluttering edible things zipping about in space.

There are two further, interrelated, reasons Akins offers for thinking the bat does not integrate sensory information during prey-capture. The first has to do with the sequencing of the information flow. As the bat progresses through its routine in three phases (search, approach,

[5] And notwithstanding the presence of some highly selective auditory neurons, the bat's brain may well also contain other populations sensitive to wider ranges of stimuli.

and terminal) its informational needs change, and the bat accordingly adjusts its chirping. The content of the returned sonar signal shifts along with the bat's informational requirements and "[i]nformation that is not needed at the end of [each stage of] the behavioral sequence is simply 'dropped'" (Akins 1993, p.150). For instance, during the terminal phase of the capture routine the bat only "has very precise information about the target range, but probably little else" (p.151). Second, Akins offers the apriori consideration that there would be no adaptive pressure for data from earlier stages to be preserved in memory. Compared to the "massive integration" (p.150) of information in human vision, it appears unlikely "that sonar information is saved and integrated into perceptions of a stable objective world" (p.151). Then again, along with mammals, and even vertebrates, bats have a general capacity for short-term or "working" memory. So the apriori consideration actually cuts the other way—there's no reason to suppose evolution would favor disabling working memory just to screen out useless information that will rapidly fade. As the whole sequence from detection to capture transpires over only *half a second*, there is not much of a load on the bat's memory resources anyway (Bradbury and Vehrencamp 1998, p.868).

In fact, the bat does rely on prior information to guide its pursuit. If a moth somehow outmaneuvers its nemesis in the terminal phase, the bat does not revert to searching mode as, one would expect if it were an automaton following a tight script, but instead appears to remember what it is chasing. As Akins herself notes (1993, p.137), the bat will adapt either by continuing the terminal-phase, or reverting to approach-phase chirping. This makes sense if it is representing a moth as very near, and is strikingly unlike the idiotic loops that sphexish organisms can get trapped in, such as snakes which need to restart the entire hunting sequence if a target evades them (Dennett 1998, p.346). It seems plausible that the bat keeps data from the search and approach phases so that it can improvise if something goes wrong. So, in accord with her Strawsonian-inspired theorizing, the bat maintains an awareness of, and can re-identify, a moth that has temporarily fluttered out of "view."

Outside of hunting, there is also evidence that bats construct "an internal model of sonar

acoustics" including a "dynamic image of the bat's surroundings" (Simmons, 2012) and "spatial maps" useful for navigation and obstacle avoidance (Bradbury and Vehrencamp 1998, p.870; Simmons *et al.*, 1990). Bats use echolocation to distinguish between types of trees by attending to the differing acoustical properties of needle-like leaves versus those that are broad and flat (Grunwald *et al.*, 2004). Bats are also known to be capable of recognizing objects defined by multiple acoustical components (Simmons *et al.*, 1990). Schnitzler *et al.* (2003, p.387) argue that echolocation first evolved to help bats spatially orient for short-term navigation and its use in hunting came later. Echolocation is known to enable the use of "flyways" in dark, crowded, conditions to locate roosts and landing sites. In one experiment, bats altered their flight patterns and sonar pulses in response to the placement of an obstacle in the flight corridor. These orienting reactions subsided in time, presumably once their spatial maps were updated to accommodate this new feature of the terrain (p.388).[6]

So far I have been questioning the first premise of Akins' argument. The evidence from physiology and echolocation behavior does not support the contention that they are guided by instincts and stimulus-response gimmicks. Another problem with the first premise is that Akins tries to draw a general conclusion on the basis of only one aspect of the sensory repertoire: echolocation. The inference from saying that "the sonar system of the bat is probably *not* concerned with the representation of three-dimensional objective particulars" to the conclusion that "it makes little sense to attribute *to the bat* a phenomenal point of view" (Akins 1993, p.151) overlooks bats' other sensory capacities. Even if it turned out that bat *echolocation* does not include spatial representation, this would hardly show that there is nothing it is like to be a bat, given that their point of view may draw on spatial representations employed in visual perception. Likewise, that an animal is often disposed to stereotyped movements in some respects does not show that it is completely inflexible in every way. Here the distinction between *mental-state*

[6] Are cognitive maps necessary or sufficient for global representation? Perhaps they aren't sufficient—a robot guided by GPS can navigate. Are they necessary? That's also contentious since it depends on one's theory of mental representation (e.g. are representations map-like or sentence-like?).

and *creature* consciousness is germane. As a conscious *creature* could have non-conscious perceptual states, there is a big difference between saying that bats are unconscious versus saying that *echolocation* is unconscious. The latter view is compatible with a weak skepticism treating echolocation as analogous to other forms of non-conscious "sensation," such as blindsight, the "vomeronasal" system, (Keeley 2011, p.236), or even "deaf-hearing" (Engelien *et al.*, 2000). Perhaps bats are conscious, just not with respect to echolocation. I think this possibility is doubtful, but it is at least worth mentioning.

If we turn to consider vision, the picture that emerges is strongly suggestive of integrated representation and consciousness. The (mainly) non-echolocating megachiroptera, or old-world fruit bats, have excellent color vision, though Akins' focuses on *Myotis lucifugus*, a microbat echolocator. The importance of sight in this insectivorous subgroup has been grossly underestimated until somewhat recently. These, as Akins herself admits, "are not blind even if somewhat myopic" (Akins 1993, p.129). Actually, while the physical characteristics of sound limits echolocation to short-range discriminations (of not more than a few dozen centimeters), microchiroptera vision is not adequately described as nearsighted. Compared to our understanding of echolocation, our comprehension is at an immature stage, but we do know they are far from myopic. Moreover, research on bat vision also challenges the claim that they are generally "boring" or prone to behavioral scripts. Bats coordinate echolocation with other modalities, responding flexibly to their environment.

Continuing research is contributing to a picture of microbat vision quite at odds with the one offered by Akins (and others, such as Dennett). Microbats employ vision at a variety of ranges. One set of experiments showed that bats disregarded echolocation at short range, relying on vision to select escape routes (Chase 1981). Joermann *et al.* (1988) found that bats also use vision beyond the range of echolocation when orienting towards landing sites. Field studies of homing behavior in microbats suggests that they visually orient using such medium-sized landmarks as clumps of trees, bushes, fences, and small rock formations (Layne 1967). Bats have migratory patterns similar to many birds, suggesting they need vision for long-distance

navigation. This list of possible visual cues also includes simulated stars (Childs & Buchler 1981) and post-sunset glow (Buchler & Childs 1982).

In fairness, Akins acknowledges "outstanding questions" about the bat's other activities and possible knowledge of "permanent objects and structures, and about the integration and overlap of sonar information with other sensory modalities" (Akins 1993, p.158 n.24). She also notes that they live in "complex caves, have permanent roosts, hunt in preferred places and can locate and identify their young in a crowded communal roost" (Akins 1993, p.158 n.24), and, at one point, even concedes they "are not genuinely boring, for they adapt their signals and behavior to the situation at hand" (p.137). So, Akins' skepticism should be seen as modulated by these other considerations. The fact that some bats remember which individuals have shared food with them (Wilkinson 1984, 1988) also suggests more robust integrative and memory capacities. A look at the empirical literature on bat vision fleshes out these counter-skeptical second thoughts.[7]

Earlier homing experiments in the field failed to properly illuminate the importance of vision in bat perception because of interactions between blinded bats and sighted control subjects released simultaneously. Layne (1967) reports a noteworthy incident involving a disoriented blindfolded bat. Soon after the bat wandered into the vicinity of an unhindered conspecific whereby the pair "closed formation," remaining together while the blindfolded bat followed the movements of the "leader," until both were lost from sight. Layne suggests early studies finding no difference in homing abilities between blind and sighted bats failed to control for such serendipitous teamwork.

Back in the laboratory, studies of visual acuity also initially produced a long-series of failures. However, further efforts have largely overturned these results. Experiments have implicated vision in obstacle avoidance (Chase and Suthers 1969). Bradbury (1969) made a key discovery when bats were tested under differing lighting conditions. The sensitive nocturnal eye

[7] I am indebted to Chris Stephens for this nuance in my interpretation of Akins.

of the bat seems to function best in dim light. It is possible that earlier experiments had inadvertently blinded the bats with, what is to humans, ordinary ambient light. Intriguingly, Bell and Fenton (1986) found the best responses of certain species tested under dim lighting were markedly *superior* to human vision under similar circumstances.

The visual abilities of echolocators are often impressive. *Myotis lucifugus* is capable of discriminating moving stripes corresponding to objects about 4mm wide (Suthers 1966). If partially deafened, *lucifugus* can rely on vision to avoid 2mm-thick string barriers while flying in dim light (Bradbury 1969). Other echolocators have been trained to visually discriminate pairs of stimuli with differing shapes (as between circles and rectangles).

Although one might expect microbat vision to be atrophied since they often fly in the dark, their sight is comparable to that of other nocturnal mammals (Childs and Buchler 1981), and appears to be better than rats (Suthers 1969). Echolocation has two major drawbacks: it is useful only at short distances, and it involves a prodigious expenditure of energy. Vision makes up for this as it is useful at a variety of ranges and requires very little exertion. Hence, that bats use vision for orienting and landmark recognition makes good evolutionary sense. Bats have migratory patterns similar to birds, suggesting that they need vision for long-distance navigation. They coordinate the use of vision and echolocation in final approaches when landing.[8]

In summary, evidence about anatomy, brightness discriminations, visual acuity, the recognition of patterns, landmarks, and small objects, suggests that bat vision, while generally poor by human standards, nevertheless employs representations of the spatial properties of persisting objects. Both in the laboratory and in the field, bats are visually responsive to geometric forms and middle-sized objects. Bats are not sphexish automatons. Vision complements echolocation and facilitates non-rigid behavioral patterns. The claim that they do not conceptualize the world, somewhat as we do, seems at odds with much of the fieldwork and laboratory results.

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[8] Johan Elköf deserves credit for the points made in this paragraph.

V. IMPLICATIONS FOR NEUROPHILOSOPHY

Now it is time to consider the broader significance of this discussion in light of the distinction made earlier between strong and weak neurophilosophy. To what extent does Akins' investigation advance the cause of SN? This question can be examined in two respects corresponding to what Allen (2010) calls the "distribution problem," and, the "phenomenal problem." The distribution problem is the question as to who and what is conscious, while the phenomenal problem is about knowing the specific character of an animal's subjective experience, that is, its perceptual phenomenology, or, what it is like. SN might contribute solutions in one of two ways: either by delivering an empirically grounded solution that invokes troublesome concepts, such as phenomenal consciousness, or, by forcing their revision or elimination, transforming the philosophical problem into an empirical one.

Beginning with the distribution problem, SN might offer an answer by way of a successful operationalization of the concept of consciousness. An empirical solution to the problem of other animal minds might draw on the strength of an analogy between human and animal minds. Even Nagel (1974/1998, p.528) acknowledges the three crucial points of interest: (a) our shared evolutionary history with bats and other mammals, (b) similar physiologies, and, (c) behavior. His appeal to commonalities in behavior, functional structure, and descent is plausible and familiar. So much for philosophical puzzlement, one might be tempted to think.

However, things are not so simple. It is not clear *how strong* an analogy is required to merit an attribution of consciousness to a non-human bearing only a degree of resemblance.[9] Some animals ought to be judged non-conscious in light of their dissimilarity to humans (Allen, 2010), or perhaps in light of their similarity to non-conscious perceivers, such as blindsight patients (Carruthers, 1992; Allen-Hermanson, 2008). Sorting this out is not a strictly empirical matter, since it raises issues about the ultimate nature of consciousness: Is it a natural kind? What marks, or surface properties, are associated with it, and which characteristics are essential

[9] Might this (finally) call for an application of "similarity-based" supervenience (Kim, 1987)?

versus those that are merely contingent? Is it the kind of property that depends on overall functioning, or, physical implementation (i.e. is it a role or realizer property)?[10] Or, if consciousness admits of degrees, how is that to be understood? As resolving these issues partly depends on what one thinks about controversial thought experiments involving intelligent androids, the Chinese Room, and other exotics, entanglement with metaphysical theory appears to be unavoidable. Or, to put the point less tendentiously, it is hardly obvious that adherence to SN allows the distribution problem to just wither away.

Akins's own viewpoint aptly, though inadvertently, illustrates. Attending closely to neuroscience did not lead to the conclusion that bats lack a point of view—except in the "weak" sense that constraints on what a bat represents places constraints on its (possible) conscious contents. It was only within this limited scope that neurophysiology was "pertinent" and concerns about subjectivity were "brought into sharper focus." Indeed, Akins acknowledges as much when she allows it was inevitable that philosophical annoyance about qualia and subjectivity would pass untouched (1993, p.154). She admits "it was disappointing to see how very little insight into the bat's subjective state was gained" (p.152), and even more pessimistically, states "no stand could be taken on whether it is like anything" to be a bat (p.154). The remaining conceptual difficulties, such as the status of representations, are nonetheless explained away as a consequence of the immaturity of the sciences (p.153): There are many unanswered questions such as how to distinguish coding from noise, how to "scale up" interactions between neurons and sub-assemblies, and how to sort out the many partly overlapping positive and negative characterizations offered by the data.

She also appears to equivocate between the mundane sense that science is privileged when it comes to understanding the nature of nervous systems, and the promise of something like a revolution in our comprehension. On the one hand, she rejects the method of first philosophy, and the notion of strictly philosophical truths, in favor of taking the other route informed by the

[10] In answer to Block's question "how can science based on us generalize to creatures that don't share our physical properties?" (2002, p.16), it can be replied that they may nevertheless share our functional properties.

natural sciences. Nevertheless, she also finds it necessary to traffic in traditional first philosophy in the form of a Strawsonian theory founded on introspection and apriori conceptual analysis. This is not urged upon us by empirical theory about bats![11] Her approach to the distribution problem *presupposes* that we have a preliminary theory of consciousness derived from philosophical theorizing about human beings ready for deployment.

Statements like "science has something to say about consciousness," or "science is encroaching on traditional philosophical concerns" also seem to vacillate between WN and SN. Perhaps Akins wouldn't really agree with SN, or, perhaps she hasn't made up her mind. On one reading my dispute with her reduces to an in-house quarrel about whether a Representationalist theory of consciousness applies to bats. The modest conclusion is that self-avowed neurophilosophers should be more reflective and more forthcoming about their stance on natural epistemology. The immodest conclusion is that we haven't been given any grounds for thinking that phenomenal consciousness in bats is becoming naturalized, or, for some, "Quined."

Turning to the phenomenal problem, the prospects for SN again look unfavorable. Can we agree that "philosophers have thought that one cannot know what it is like to be a bat [nevertheless] we can know quite a lot about what it is like, even if not everything" (Macpherson 2011, p.30 n.46)? This kind of statement also appears to trade between strong and weak senses of neurophilosophy. In light of the distinction, let us reconsider what was and was not accomplished in Akins' study.

Akins does find some small gains in our understanding are purchased by the various scientific findings about signals, processing, and behavior. However, again, let this assessment be filtered by the weak/strong distinction. Philosophers such as Nagel never argued that empirical inquiry is irrelevant to probing the structure of perceptual systems. Everybody agrees that science can expand our understanding of the "schematic conception" (Nagel 1974/1998,

[11] Strawson was, of course, opposed to Quine on a range of fundamental issues, including the epistemic value of conceptual analysis and apriori philosophizing, the analytic-synthetic distinction, skepticism about meaning and reference, and, naturalized epistemology.

p.521), e.g. three-dimensional forward perception with a range of three feet. While this work is interesting, the results only support the weakly neurophilosophical program of discovering negative constraints and positive characterizations. Understanding wasn't purchased or transformed by scientific results, save for swapping one topic (subjective consciousness) for another (the reporting of scientific findings on objective phenomenology).

In "A Bat Without Qualities" Akins admits there's an "intuitive pull" to the claim that we will fail whenever we try to imagine the qualitative experience of an organism whose sense organs differ radically from our own, regardless of our grasp of its objective phenomenology (1996, p.347). This, according to Nagel, is because phenomenal experience is essentially connected to having a subjective point of view, whereas science is essentially viewpoint independent. When cast this way, Akins agrees, "the problem of understanding seems insuperable" (p.347). However, she contends Nagel's assessment incorrectly assumes informational processing functionality (and representational content) is conceptually separable from qualitative feel. She challenges this assumption by way of a thought experiment showing that it is impossible to conceive of the qualitative look of a messy office while eliminating the representational content of the imagery (1996, p.353). The way the papers are scattered on the desk has a certain look. But how can we subtract literally all of the representational content (including colors, shapes, etc) from our conception? Though this should be possible, if there is a distinction between the qualitative and the representational, "you can't imagine that…This, I contend, is not something we have any idea how to do…we have no inkling how to pull them apart or put them together. Our intuitions do not provide a concrete distinction" (p.353).

What are we to make of this? In fact, there is an error in her reasoning. Let us assume Akins is correct (I think she is) in saying that qualitative feel always seems to be *of* something *as* something, or, in other words, that content cannot be eliminated from phenomenal feel. While this central insight motivating Representationalist theories of consciousness is not universally held (Peacocke 1983; Block 1995, 1996), it is plausible and influential (Lycan, 2006, dubs this uncontroversial view "weak" Representationalism). But this is compatible with the intuition that

qualitative feel cannot be reduced to, or derived from, those contents (Lycan 2006). The phenomenal problem cannot be dismissed so easily.

Another response to the complaint that neuroscience will always leave something out, (i.e. the qualia) is offered by Churchland (2005, p.289), who retorts that this incorrectly assumes grasping the successful theory of consciousness would cause one to undergo new experiences: "Why should anyone expect that understanding the theory must result in the production of the phenomenon the theory addresses?" she asks. Just as a complete understanding of pregnancy doesn't make one pregnant, understanding the neurophysiological basis of smelling mint will not cause one have that experience, she argues.

This reply, however, comes down to a questionable analogy. If a theory leaves something out that could contribute to understanding, then it is not a "genuine" (complete) explanation after all. The theory should fill in all the gaps. There is no reason to think there are concepts pertaining to the understanding of pregnancy that cannot be conveyed to those who are not pregnant.[12] This is because exemplifying the target phenomenon is not presupposed by a grasp of the concepts explaining it. However, when it comes to consciousness, there is some reason to think things are different. Perhaps smelling mint requires the acquisition of a certain (minty) phenomenal concept, and to possess it entails one can at least *imagine* what that experience is like (that is, if this is short of literally *generating* the experience). If a complete understanding of minty experience requires the grasp of this phenomenal concept, and if the best scientific theory does not confer it, then the theory leaves something out that is part of a complete understanding. That many, or most, theories do not generate their target phenomena is irrelevant. Expectations about the theory of consciousness might be different in light of an intimate bond between first-person experience and the acquisition of phenomenal concepts.

However, even if the point is conceded to Churchland, the implication is not SN-friendly. If the only way to acquire certain concepts is by having experiences, then this does

[12] Of course, what it is like to be pregnant would be left out, but noting that fact does no favors for Churchland's argument.

not bode well for an empirical solution to the phenomenal problem about bats. If this is right, then SN will not tell us what echolocation is like. Perhaps the easiest way to deal with recalcitrant first-person phenomenal feels is just to ignore them, or otherwise eliminate them from neurophilosophical theorizing. But, there does not seem to be any *pressure* to do so as a result of an SN-guided investigation into animal perception. How could there be?

VI. CONCLUSION

In taking stock of the neurophilosophical movement, there are undoubtedly many successes to be acknowledged. All the same, neurophilosophers have begun to express disappointment, such as with the co-evolutionary framework. One lack of progress is when it comes to integrating explanatory levels, from cellular activity up through networks, and on to cognition and consciousness. This is but a "distant dream," at the moment (Bickle *et al.*, 2012). I have been emphasizing the apparent limitations of the strong version of neurophilosophy when it comes to animal consciousness. What successes justify the predicted irrelevance of the old paradigm? What questions have been dissolved? The weak sense, meanwhile, was entirely vindicated, of course.

More constructively, I have also argued that bats token unified representations of the everyday world of rocks, trees, prey, and each other. A reconsideration of the empirical results shows that bats are not boring automatons driven by short input-output loops employing instincts and reflexes. Bats satisfy a range of philosophically and scientifically interesting elaborations of the general idea that consciousness is best understood in terms of representational functions.

Finally, the pursuit of objective phenomenology, though philosophically uncontroversial, is genuinely interesting, and can prompt tantalizing speculation about the minds of other animals. But absent our human awareness of first-person appearances, the phenomenal problem is hopeless. Nevertheless, I will close with a suggestion about what it is like for bats. Against those who claim that echolocation is a kind of vision (or perhaps some unknowable blend of vision and audition), I would argue that it is really just a form of audition. By drawing on the example of human expert echolocators who undergo (admittedly odd) auditory experiences, the

qualitative character of echolocation may be accessible to human understanding after all. Unfortunately this approach is of no use when it comes to animals whose modalities we do not share.

References

Akins, K. (1993). "What is it Like to be Boring and Myopic?" in B. Dahlbom (Ed.), *Dennett and His Critics* (pp.124-60). Oxford: Blackwell.

Akins, K. (1996). "A Bat Without Qualities," in M. Bekoff and D. Jamieson (Eds.) *Readings in Animal Cognition* (pp.345-58). Cambridge: The MIT Press.

Allen-Hermanson, S. (2008). "Insects and the Problem of Simple Minds: Are bees natural zombies?" *The Journal of Philosophy* 105(8): 389-415.

Allen, C. (2010). "Animal Consciousness," *The Stanford Encyclopedia of Philosophy* (Summer 2012 edition), Edward N. Zalta (ed.). <http://plato.stanford.edu/entries/consciousness-animal/>

Baars, B.J. (2005). "Global Workspace Theory of Consciousness: Toward a cognitive neuroscience of human experience," *Progress in brain research* 150: 45-53.

Bell, G.P. and Fenton, B. (1986). "Visual Acuity, Sensitivity and Binocularity in a Gleaning Insectivorous Bat, *Macrotus californicus* (Chiroptera: Phyllostomidae)," *Animal Behavior* 34: 409-14.

Bickle, J. (2005). "Replies," *Phenomenology and the Cognitive Sciences* 4(3): 285-96.

Bickle, J., Mandik, P., and Landreth, A. (2012). "The Philosophy of Neuroscience," *The Stanford Encyclopedia of Philosophy* (Summer 2012 edition), Edward N. Zalta (ed.). <http://plato.stanford.edu/archives/sum2012/entries/neuroscience/>

Block, N. (1995). "On a Confusion about a Function of Consciousness," *Behavioral and Brain Sciences* 18: 227-47.

Block, N. (2002). "The Harder Problem of Consciousness," *Journal of Philosophy* 99: 391-425.

Bradbury, J.W. (1969). "The Use of Vision by the Little Brown Bat, *Myotis Lucifugus*, Under Controlled Conditions," *Animal Behavior* 17: 480-5.

Bradbury, J.W. and Vehrencamp, S.L. (1998). *Principles of Animal Communication*. Sunderland, MA: Sinauer Associates.

Brook, A. and Mandik, P. (2007). "The Philosophy and Neuroscience Movement," *Analyse &*

Kritik 29 (1): 3-23. <http://www.analyse-und-kritik.net/en/2007-1/AK_Brook_Mandik_2007.pdf>.

Buchler, E.R. and Childs, S.B. (1982). "Use of the Post-Sunset Glow as an Orientation Cue by Big Brown Bats (*Eptesicus Fuscus*)," *Journal of Mammalogy* 63: 243-7.

Carruthers, P. (1992). *The Animals Issue*, Cambridge: Cambridge University Press.

Carruthers, P. (2000). *Phenomenal Consciousness: A naturalistic theory*. Cambridge: Cambridge University Press.

Chase, J. (1981). "Visually Guided Escape Responses of Microchiropteran Bats," *Animal Behavior* 29: 708-13.

Chase, J. and Suthers, R.A. (1969). "Visual Obstacle Avoidance by Echolocating Bats," *Animal Behavior* 17: 201-7.

Childs, S.B. and Buchler, E.R. (1981). "Perception of Simulated Stars by *Eptesicus Fuscus* (Vespertilionidae): A potential navigational mechanism," *Animal Behavior* 29: 1028-35.

Churchland, P.S. (1983). "Consciousness: The transmutation of a concept," *Pacific Philosophical Quarterly* 64: 80-95.

Chuchland, P.S. (1986). *Neurophilosophy*. Cambridge: The MIT Press.

Churchland, P.S. (1987). "Epistemology in the Age of Neuroscience." *The Journal of Philosophy* 84(10): 544-53.

Churchland, P.S. (2005). "A Neurophilosophical Slant on Consciousness Research," in V.A. Casagrande, Ray W. Guillery, and S. Murray Sherman (Eds.). *Progress in Brain Research 149: Cortical function: A view from the thalamus* (pp.285-94). Amsterdam: Elsevier.

Dahlbom, B. (1993). "Editor's Introduction," in B. Dahlbom (Ed.) *Dennett and his Critics* (pp.1-12). Oxford: Blackwell.

Dawkins, R. (1986). *The Blind Watchmaker*. New York: Norton.

Dennett, D.C. (1993). "Back From the Drawing Board," in B. Dalhbom (Ed.) *Dennett and His Critics* (pp.203-35). Oxford: Blackwell.

Dennett, D.C. (1998). "Animal Consciousness: What matters and why," *Brainchildren: Essays on designing minds*. Cambridge: The MIT Press.

Dretske, F. (1995). *Naturalizing the Mind*. Cambridge: The MIT Press.

Engelien, A., Huber, W., Silbersweig, D., Stern, E., Frith, C., Döring, W., Thron, A., and Frackowiak, R.S.J., (2000). "The Neural Correlates of 'Deafhearing' in Man: Conscious sensory awareness enabled by attentional modulation," *Brain*, cxxiii (2000): 532-45

Fuzessery, Z.M. (1986). "Speculations On the Role of Frequency In Sound Localization," *Brain, Behavior and Evolution* 28(1-3): 95-108.

Giere, R. (1988). *Explaining Science: A cognitive approach*. Chicago: University of Chicago Press.

Gillett, G.R. (1991). "The Neurophilosophy of Pain," *Philosophy* 66(256): 191-206.

Goldman, A. (1985). *Epistemology and Cognition*. Cambridge: Harvard University Press.

Griffin, D.R. (1992). *Animal Minds*. Chicago: University of Chicago Press.

Grunwald, J., Schörnich, S., and Wiegrebe, L. (2004). "Classification of natural textures in echolocation," *Proceedings of the Natural Academy of Sciences* 101(15): 5670-4.

Hardcastle, V. (1997). "When a Pain is Not," *The Journal of Philosophy* 94(8): 381-409.

Joermann, G., Schmidt, U., and Schmidt, C. (1988). "The Mode of Orientation During Flight and Approach to Landing in Two Phyllostomid Bats," *Ethology* 78: 332-40.

Keeley, B.L. (2002/2011). "Making Sense of the Senses: Individuating modalities in humans and other animals," in F. Macpherson (Ed.). *The Senses: Classic and Contemporary Philosophical Perspectives* (pp.220-40). Oxford: Oxford University Press.

Kim, J. (1987). "'Strong' and 'Global' Supervenience Revisited," *Philosophy and Phenomenological Research* 48(2): 315-326.

Kolb, B. and Whishaw, I.Q. (2003). *Fundamentals of Human Neuropsychology*. New York, NY: Worth Publishers.

Layne, J.N. (1967). "Evidence for the Use of Vision in Diurnal Orientation of the Bat *Myotis Austroriparius*," *Animal Behavior* 15: 409-15.

Lycan, W. (1996). *Consciousness and Experience*. Cambridge: The MIT Press.

Lycan, W. (2006). "Representational Theories of Consciousness," *The Stanford Encyclopedia of Philosophy* (Summer 2012 edition), Edward N. Zalta (ed.). <http://plato.stanford.edu/archives/sum2012/entries/consciousness-representational/>

Macpherson, F. (Ed.). (2011). *The Senses: Classic and Contemporary Philosophical Perspectives*. Oxford: Oxford University Press.

Mandik, P. (2007). "The Neurophilosophy of Consciousness," in Max Velmans and Susan Schneider (Eds.) *The Blackwell Companion to Consciousness* (pp.418-30). Blackwell Publishing.

Mandik, P. (2009). "The Neurophilosophy of Subjectivity," in John Bickle (Ed.) *The Oxford Handbook of Philosophy and Neuroscience* (pp.601-18). New York: Oxford University Press.

Nagel, T. (1974/1998). "What Is It Like to Be a Bat?" *Philosophical Review* 83 (435-50) reprinted in N. Block, O. Flanagan, and G. Güzeldere (Eds.). *The Nature of Consciousness: Philosophical Debates* (pp.519-27). Cambridge: The MIT Press.

Peacocke, C. (1983). *Sense and Content*. Oxford: Oxford University Press.

Rosenthal, D. (1986). "Two Concepts of Consciousness," *Philosophical Studies* 49: 329-59.

Schnitzler, H.U., Moss, C.F., and Denzinger, A. (2003). "From Spatial Orientation to Food Acquisition in Echolocating Bats," *Trends in Ecology and Evolution*. 18 (8): 386-394.

Simmons, J.A. (2012). *Current Opinion in Neurobiology* 22(2): 311-9.

Simmons, J.A., Moss, C.F., and Ferragamo, M. (1990). "Convergence of Temporal and Spectral Information Into Acoustic Images of Complex Sonar Targets Perceived By the Echolocating Bat, *Eptesicus fuscus*," *Journal of Comparative Physiology A.* 166: 449-70.

Strawson, P.F. (1959). *Individuals*. New York: Doubleday and Co.

Suga, N. "The extent to which biosonar information is represented in the bat auditory cortex," *Dynamic aspects of neocortical function* (1984): 315-73.

Suthers, R.A. (1966). "Optomotor Responses by Echolocating Bats," *Science* 152: 1102-4.

Suthers, R.A. and Braford, B. (1969). "Visual Form Discrimination by Echolocating Bats," *Biological Bulletin* 137: 535-46.

Tye, M. (1995). *Ten Problems of Consciousness.* Cambridge: The MIT Press.

Tye, M. (2000). *Consciousness, Color, and Content*. Cambridge: The MIT Press.

Wilkinson, G. (1984). "Reciprocal Food Sharing in the Vampire Bat," *Nature* 308: 181-4.

Wilkinson, G. (1988). "Reciprocal Altruism in Bats and Other Mammals," *Ethology and Sociobiology*: 85-100.