



Pictures, Plants, and Propositions

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Abstract

Philosophers have traditionally held that propositions mark the domain of rational thought and inference. Many philosophers have held that only conceptually sophisticated creatures like us could have propositional attitudes. But in recent decades, philosophers have adopted increasingly liberal views of propositional attitudes that encompass the mental states of various non-human animals. These views now sit alongside more traditional views within the philosophical mainstream. In this paper I argue that liberalized views of propositional attitudes are so liberal that they encompass states of all sorts of apparently mindless systems like circadian clocks in plants. I begin by arguing that on the most well-developed and widely endorsed theories of underived representation in philosophy, circadian clocks qualify as representations. I then argue that standard reasons for thinking that perceptual states and pictures have propositional content carry over to circadian clocks. Finally, I argue that circadian representations in plants play the kind of functional role that is widely taken to be partly constitutive of belief-like attitudes. So according to mainstream theories of representation, propositions, and attitudes, plants have propositional attitudes. Yet on other more traditional views, this conclusion would seem absurd. So, contrary to appearances, there is no shared, stable understanding of what propositional attitudes are in contemporary philosophy.

Keywords Circadian clocks · Intentionality · Perceptual content · Plant intelligence · Propositional attitudes · Representation

1 Introduction

Philosophers and psychologists have traditionally regarded propositions as the domain of rational thought and inference. Influenced by the pioneering work of Frege and Russell, analytic philosophers have held that propositional attitudes play an essential role in the etiology of rational thought and action, and indeed lie at the

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core of our commonsense conception of the mind (Davidson 1963; Fodor 1987a; Sellars 1956). An influential strand in this tradition holds that the possession of determinate propositional attitudes depends on the possession of lexical concepts, and hence that non-linguistic creatures lack propositional attitudes (Davidson 1982; Stich 1983). A more recent manifestation of this philosophical tradition holds that our knowledge of *how to do something* necessarily involves propositional content, and is thus an expression of rational intelligence (Stanley and Williamson 2001). This view is regarded as heterodox in certain respects, but it is thoroughly traditionalist in assuming that states with propositional content *ipso facto* lie within the domain of rational, intellectual faculties.

This traditional connection between propositional states and rational thought is also found throughout the cognitive sciences. Cognitive psychologists standardly distinguish ‘explicit’ consciously accessible forms of memory from ‘implicit’ procedural memory on grounds that the former has propositional content (Tulving 1983). Similarly, in learning theory it is widely assumed that ‘higher’ cognitive processes involve the manipulation of states with propositional content, whereas ‘lower’ reflexive or habitual processes merely involve associative links between stimuli (Anderson 1980; Dickinson 1980; Mitchell et al. 2009; Shanks 2007). Indeed, this dichotomy is entrenched in comparative psychology where it frames a contemporary version of *Morgan’s Canon* (Morgan 1894): We shouldn’t explain animal behavior in terms of propositional states if we can explain it in terms of ‘lower’, associative processes. While many ethologists now agree that animals are capable of rational inference, they seem to think that this turns on whether animals have internal states with propositional content (Mitchell et al. 2009).¹

Since the late 20th century, philosophers have adopted increasingly liberal views about the nature and scope of propositional attitudes, views that recognize the existence of propositional attitudes far outside the traditional domain of the rational, conceptually sophisticated intellect. This liberalization of views about propositional attitudes is partly due to the influence of the *non-conceptualist* idea that perceptual experience might represent certain properties even if the perceiver lacks the concepts needed to generally grasp those properties in thought (Evans 1982; Peacocke 1992). Liberalization is also partly due to the influence of *non-structuralist* views about the metaphysics of propositions, which reject the traditional Fregean and Russellian assumption that propositions are structurally isomorphic with the logical forms of the sentences used to express them. Together these views make room for the idea that a representational state might have propositional content even if the representational system lacks sophisticated conceptual or inferential capacities. Schroeder (2006) gives voice to such a view, in a way that I think many other contemporary philosophers would find congenial: “I think of propositional contents as individuated not by the concepts their entertainers deploy, but by how things must be in the world for them to be satisfied. When a lizard desires a fly, the way things

¹ As I hope will become clear later, I am not here intending to cast a skeptical light on the *extensional* adequacy of these scientific distinctions (here, at least). The question I am interested in is whether the notion of a propositional attitude is empirically grounded enough to capture these distinctions.

must be in the world for the lizard's desire to be fulfilled is that the lizard catch and consume the fly" (p. 166).

Such liberalized views of propositional attitudes now sit squarely within the mainstream of contemporary philosophical opinion. In this paper I will argue that certain mainstream liberal views are in fact so liberal that they encompass states of systems that most of us would ordinarily think of as utterly mindless, such as plants.² This consequence is in serious tension with traditional views, which also remain well within the mainstream. The traditional view that propositional attitudes are the domain of rational inference is not threatened *too* much by the idea that lizards have propositional attitudes; lizards aren't the smartest critters, but at least they plausibly have minds and can act on the basis of primitive reasons. But the traditionalist would likely find the view that *plants* have propositional attitudes radically implausible, even absurd. Yet this dramatic divergence between mainstream views of propositional states and attitudes seems to be largely unnoticed in the literature.

I should clarify two points about the scope of my thesis before moving on. First: Is this news? Aren't there widely recognized views in philosophy and cognitive science on which thermostats and all sorts of other putatively mindless systems might qualify as having propositional attitudes (Dennett 1987; McCarthy 1979)? On these liberal 'interpretivist' views, *what it is* for a system count as a locus of propositional attitudes is simply for its behavior to be amply and accurately predicted through the ascription of propositional attitudes.³ Occurrent propositional attitudes are not regarded as *real* in the sense of being concrete particulars with causal powers. Since explanatory success is widely regarded as the best possible reason to believe in the reality of a theoretical entity, liberal interpretivists have struggled to explain why their view doesn't just collapse into some form of realism (Dennett 1991). Interpretivists have distinguished their view from standard realisms by holding, on grounds of evolutionary continuity, that there is unlikely to be a bright line in nature between systems whose behavior is richly explained by propositional attitudes and systems whose behavior is not (Dennett 1987). But one can believe there are real and interesting distinctions between evolved biological systems without believing there are bright lines that demarcate their essential natures (Ruiz and Umerez 2018). There are, presumably, *some* interesting distinctions between us and the first self-replicating molecules.

In any case, while liberal interpretivism and other non-realist views of propositional attitudes are widely recognized in the literature, they are not widely endorsed. Since the 1960's, mainstream views of propositional attitudes have been decidedly *realist*. So strong is the prevailing presumption against liberal interpretivist views that the fact that such views encompass thermostats and plants is often taken to

² I recognize that several philosophers and biologists have recently drawn from the scientific literature on 'plant intelligence' to argue that plants indeed have minds (Maher 2017; Gagliano 2017; Calvo 2017). I don't dispute this claim here. I largely prescind from empirical theses in this paper to explore the commitments about different views of propositional representation.

³ Not all interpretivist views are liberal. According to Davidson's (1973, 1982) version of interpretivism, only language-using systems have propositional attitudes.

provide a *reductio* of those views (Fodor 1987b; Searle 1980). Realists hold that there are certain functional and semantic features that simply aren't exhibited by these simple systems, like "direction of fit, propositional content, and conditions of satisfaction" (Searle 1980, p. 420). Even *radical* realists who would ascribe propositional attitudes to insects would draw the line at plants and thermostats, on grounds that they're not equipped with a cognitive architecture in which beliefs and desires control action (Carruthers 2004). These realist views are the targets of this paper, not heterodox interpretivist views. I will argue that even on certain mainstream views of propositions and attitudes, the functional and semantic criteria just mentioned actually *don't* preclude plants from having propositional attitudes.

The second clarificatory point I wish to make is this: I take no stand in this paper on whether or not plants *in fact* have propositional attitudes. The thesis of this paper is a conditional: *if* certain mainstream views of propositional attitudes are correct, *then* plants have propositional attitudes. I leave the reader to *ponens* or *tollens* as she sees fit. She might take the argument to provide a *reductio* of liberalized views of propositional attitudes on grounds that we have far stronger reasons to think that plants lack propositional attitudes than we have for endorsing currently fashionable philosophical theories. Conversely, she might recognize that traditional views of propositional attitudes themselves are just theoretical trends that became entrenched, and take the explanatory power of liberal views to show that our prior sense of the scope of propositional attitudes was merely parochial.⁴ Taking this route, the inferential options ramify further. The reader might take the mindlessness of plants as a fixed point, and infer that propositional attitudes are not inherently psychological. Alternatively, she might take the psychological nature of propositional attitudes as given, and infer that plants have minds. It's all up for grabs.

That's the central lesson I hope the reader will draw from this paper: that there is presently no stable, shared understanding of the empirical extension of the notion of a propositional state in philosophy or psychology. Mainstream realist views of propositional attitudes are in fact radically divergent. The situation is not just one in which theorists disagree about precisely how to characterize a phenomenon whose nature and scope they have a shared pre-theoretical grasp of. Rather, the situation is one in which theorists' antecedent grasp of the phenomenon is itself so thoroughly infused by theory that there are few empirical fixed points to guide inquiry and negotiate disagreement. Moreover, the radical divergence of mainstream views of propositional attitudes has apparently gone unnoticed; philosophers and psychologists continue to write of 'propositional attitudes', assuming their audience knows what they mean. But in a theoretical milieu in which some regard propositional attitudes as the paragon of rational discursive thought, while others hold views of attitudes that subsume putatively mindless systems like plants, this can no longer be assumed. This paper is thus partly a manifesto: a call for philosophers and psychologists to avoid writing of propositional attitudes unless they're explicit about precisely what it is in nature they're talking about. I am not so much expressing

⁴ See Ben-Yami (1997) for a sense of just how thin the historical reasons for thinking that mental states are propositional attitudes really were.

skepticism that there *are* propositional attitudes (Churchland 1981) as expressing skepticism that there are firm empirical constraints on how to resolve disagreement about the extension of ‘propositional attitude’. This is a theoretical term with no particular theoretical home.

The paper begins on common ground, with a characterization of propositional attitudes that I think is sufficiently schematic and ecumenical that it could be endorsed by virtually all mainstream realists about propositional attitudes, traditionalists and liberals alike. The characterization is this: propositional attitudes are (1) representational states with, (2) propositional content, which (3) play a specific kind of functional role. From this starting point I argue in Sect. 2 that according to the most representative, influential and well-developed theories of representation in the philosophical and psychological literature, circadian clocks in plants qualify as representations. I then argue in Sect. 3 that on mainstream views of non-conceptual content and unstructured propositions, there’s every reason to think that the representational content of plant circadian clocks is propositional. Finally, I argue in Sect. 4 that plant circadian clocks play the kind of functional role that is widely taken to be partly constitutive of belief-like attitudes, a role in virtue of which circadian content has a *thetic*, or ‘state-to-world’ direction of fit. I conclude that according to mainstream varieties of intentional realism in contemporary philosophy, circadian clocks in plants qualify as genuine propositional attitudes.

2 Representations

The cognitive sciences were able to cast off the methodological fetters of behaviorism by promising that the traditional notion of an inner mental representation could be made sufficiently precise that it might feature in causal explanations of mental processes. Philosophers and psychologists have sought to deliver on this promise by articulating theories of what cognitive representations consist in. At some mild risk of oversimplification, we can usefully distinguish two main traditions within this broad project.

The first tradition is rooted in philosophical attempts to ‘naturalize’ intentionality. Many mental states are intuitively both caused by and about specific aspects of the world. Consider seeing a green apple on a table. Your perception is presumably caused by the apple, but this doesn’t seem to involve any *ordinary* causal relation since the relation might obtain even when no apple is present to your senses, as in cases of illusion or a zap to your inferotemporal cortex (Cohen and Newsome 2004). In such cases you would be *misrepresenting* the apple.⁵ Philosophers have tried to accommodate this puzzling capacity for misrepresentation within a broadly scientific worldview by developing naturalistic theories of content that employ scientific concepts to specify the conditions under which a representational state accurately represents some aspect of the world. The most mature of these theories

⁵ I am here just reporting a dominant line of thought, not endorsing it. For some critical discussion of this way of conceptualizing and naturalizing intentionality, see Morgan and Piccinini (2017).

(e.g., Dretske 1988; Fodor 1990; Millikan 1984) share a broad family resemblance. Roughly, they hold that representations not only carry information about or *track* specific aspects of the world, they have the biological *function* of doing so.⁶ Misrepresentation occurs when a state tracks something other than what it has the function of tracking.

It is now widely recognized that these ‘tracking theories’ of content do not provide a complete theory of representation. Taken on their own they seem to massively over-generalize, encompassing all sorts of intuitively non-representational phenomena like salivation (Sterelny 1995) or pigeon droppings (Adams and Aizawa 1994). While they are officially intended as theories of what fixes the *content* of a representation, tracking theories are often tacitly assumed to provide a theory of what makes something a *representation in the first place*, and are thus taken to ‘fix the content’ of all sorts of non-representational phenomena (Ramsey 2007; Sterelny 1995). So it seems that tracking theories must be supplemented with an account of what it is for a tracking state to be ‘used’ as a representation, such that its content is explanatorily relevant to the functional role that it plays (Dretske 1988; Ramsey 2007; van Gelder 1995). Appealing to such a use-condition promises to exclude many of the problem cases; we can presumably explain the role of saliva in lubricating the oral mucosa perfectly well without ascribing content to it.

Dretske (1988) constrains a basic tracking theory of content with a use-condition to develop a rich and sophisticated theory of representation, which for present purposes we might treat as paradigmatic of mature tracking theories. Dretske holds that a state or sub-system *A* of system *S* represents entity *B* when *A* indicates the presence of *B*, and *A* is recruited, either by natural selection or individual learning, to help control *S*’s interactions with *B*, *in virtue of the fact* that *A* indicates *B*. Salivation and pigeon droppings are excluded from the domain of Dretske’s theory because they have not been selected to guide and control a system’s activities with respect to the entities they carry information about. However, I will now argue that circadian clocks in plants are not excluded from Dretske’s or other similarly mature tracking theories. Tracking theories might pick out a genuine and interesting kind of representation, but (assuming plants don’t have minds) they don’t pick out a distinctively *psychological* kind.

To see why, we should first take a close look at circadian clocks and how they work. Plants and virtually all other terrestrial organisms exhibit rhythmically patterned activities that reflect the 24 h day–night cycle. These ‘circadian’ rhythms⁷ have been recognized since antiquity, but scientific inquiry into their underlying causes began in 1729, when the French astronomer de Marian observed that the daily leaf movements of certain plants persisted even when the plants were raised in

⁶ I cannot do justice to the important differences between the views that I am classifying as tracking theories within the scope of this paper. That it is reasonable to treat these theories as variations on the same basic theme is now widely assumed in the literature (Burge 2010; Kriegel 2012; Mendelovici, 2013). I say more by way justifying this assumption in Morgan (forthcoming), where I also argue that Burge’s (2010) influential view, which is trenchantly opposed to tracking theories, is simply another variant of this same basic theme.

⁷ From the Latin ‘circa’ (approximately) and ‘diēm’ (day).

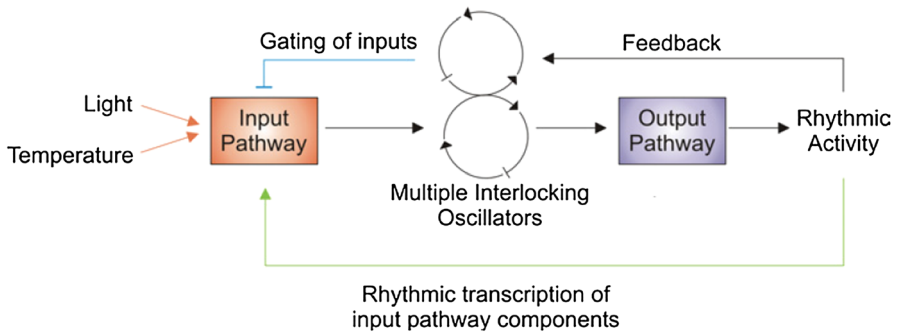


Fig. 1 The basic architecture of the circadian clock found across many biological taxa. Inputs like light and heat entrain the endogenous rhythm of multiple interlocking molecular oscillators. Oscillatory outputs control metabolic processes that mediate various adaptive rhythmic activities (from Gardner et al. 2006)

complete darkness. This suggested that circadian rhythms are driven by *endogenous* processes internal to the plant. Through the nineteenth and early twentieth centuries, physiological and selective breeding experiments that manipulated the presence of light and other stimuli over generations of organisms revealed that in the wild most clocks have an endogenous period of around 24 h (give or take 1–2 h), that it is highly heritable and robust to perturbation, but that it can also be *entrained* by environmental signals such as light and heat so as to reflect diurnal rhythms in the external world (Bünning 1973). So, for example, a wild-type plant raised under an artificial lighting cycle of 20 h might exhibit circadian rhythms entrained to this periodicity, but when moved to the dark it would likely revert to its endogenous period of roughly 24 h.

Since the 1970s, techniques of molecular genetics have started to reveal the intricate molecular mechanisms underlying circadian rhythms in a wide range of organisms. One major clue was provided by Konopka and Benzer (1971), who isolated mutant strains of *Drosophila* that exhibited arrhythmic or aberrant circadian patterns, and argued that these phenotypes likely resulted from mutations in a single gene that they called *period* (or *per*). Later developments in cloning techniques allowed *per* to be sequenced, and its corresponding mRNA transcript and protein product (PER) to be identified (Reddy et al. 1984). A few years later, Hardin et al. (1990) showed that levels of *per* mRNA and PER fluctuate in a way that reflects circadian rhythms, both in wild-type *Drosophila* as well as the mutant strains isolated by Konopka and Benzer (1971). This was the first direct evidence that circadian rhythms are produced by an oscillating molecular mechanism: a *circadian clock*. Hardin et al. proposed a model of the *Drosophila* circadian clock based on a simple negative feedback loop in which the *per* gene is first transcribed within the cell nucleus into *per* mRNA, which then makes its way into the cytoplasm where it is translated into PER, which is transported back to the nucleus where it inhibits further transcription of *per*.

Subsequent research in other organisms has revealed that the molecular mechanisms of circadian clocks are staggeringly complex and diverse, but the basic

principle of an intracellular molecular oscillator seems to be remarkably well conserved across taxa. In plants and most other organisms, the oscillator seems to comprise multiple interlocking feedback loops, unlike the simple loop described by Hardin and colleagues (see Fig. 1). This is thought to afford a degree of flexibility that allows a clock to be entrained across a wide range of possible periods (Rand et al. 2006). One feature that distinguishes circadian clocks in plants from those in animals is that clocks are distributed throughout the tissues of plants rather than being clustered in populations of neurons. But as in other animals, plant clocks are entrained by environmental stimuli like light and heat. Plants detect red and blue spectra of light using photoreceptor proteins in their leaves (phytochromes and cryptochromes, respectively), which interface with circadian oscillators via complicated signaling pathways.⁸

On the output side, circadian clocks in plants regulate transcription in a variety of gene regulatory networks, and thereby control crucial metabolic processes. In this way, plants clocks mediate several fascinating adaptive capacities of plants. For example, circadian clocks control ‘anticipatory’ leaf reorientation in *Lavatera*, allowing the plant’s leaves to face the sun in the morning, thereby maximizing photosynthesis (Schwartz and Koller 1986). Clocks in some species of *Arabidopsis* allow those plants to muster a chemical defense at the time of day they’re most likely to be attacked by herbivorous insects (Goodspeed et al. 2012). So it seems that plant circadian clocks satisfy the conditions of sophisticated tracking theories: they carry information about specific properties in an organism’s environment, and have been selected for controlling the system’s activities *because* they carry that information. Presumably a central reason why clocks in *Lavatera* control leaf reorientation, for example, is that they carry information about the day–night cycle.

The point here is not the familiar one that tracking theories of *content* over-generalize. I am focussing here on sophisticated tracking theories of representation constrained by a use-condition. To illustrate, note that not all circadian clocks qualify as tracking representations. Consider the humble Somalian cavefish, which has evolved in the perpetual darkness of subterranean caves since their ancestors were cut off from the surface of Earth roughly two million years ago (Cavallari et al. 2011). Through that process, the circadian clocks of cavefish have become partly vestigial: they still regulate metabolic activities within the cavefish, but they no longer control the fish’s activities with respect to the day–night cycle. Relieved of selective pressure to reflect the day–night cycle, they’ve evolved to have an endogenous period of roughly 47 h. These clocks would *not* qualify as tracking representations—but clocks in normal terrestrial plants would.

I should consider one objection on Dretske’s (1988) behalf. Dretske holds that a constraint on ascribing genuine content is that it must explain the behavior of *individual organisms*. He thus focusses on ‘ontogenetic’ representations, which have been selected to control behavior in virtue of what they indicate *within an organism’s lifetime*, rather than over phylogeny. He illustrates this idea with a case in which a

⁸ For more details about the properties described in this paragraph and references to the experimental literature, see Gardner et al. (2006) and McClung (2006).

bird learns to avoid eating a specific kind of insect; here it seems that an indicator of the insect is internally ‘selected’ to control avoidance behavior. But plant circadian clocks mediate individual learning, too. Gagliano et al. (2016) show that garden peas, *Pisum sativum*, can learn a conditioned response to a once-neutral stimulus, namely wind produced by a fan. Pea plants were grown in a Y-shaped ‘maze’ with two openings at the top, and were presented with training trials in which wind and light were presented simultaneously in one opening or the other. Unsurprisingly, plants grew toward the opening with the light, demonstrating their unconditioned phototropism. But plants still grew toward the wind even when it was presented alone, evidencing a conditioned response. Crucially, conditioning was mediated by the circadian clock; it tended only to occur during the ‘day’ phase of the clock.⁹ So plant clocks *do* mediate flexible mappings between stimuli and response, in virtue of their content, within an organism’s lifetime.¹⁰

Let us now turn to the second main tradition of theorizing about representation. This tradition is rooted in the idea that cognitive representations are analogous to inner scale models, which can be used to reason about systems in the external world in virtue of embodying the same abstract structure as those systems (Craik 1943). Proponents of this ‘structural’ view of representation typically spell out the relevant notion of structure by appealing to the mathematical notion of a *homomorphism* (Cummins 1996; Isaac 2013; Palmer 1978; Shepard and Chipman 1970). The psychologist Randy Gallistel (1998, 2008) has articulated the most detailed and precise homomorphism-based view of representation I am aware of, so just as we did with Dretske’s tracking theory, we might take Gallistel’s theory as paradigmatic of mature structural theories of representation. Gallistel holds that a system *A* counts as a representation of a system *B* just in case there is a homomorphism between *A* and *B*, this homomorphism is established and sustained by causal relations between *A* and *B* such that *A* carries information about *B*, and *A* is enlisted to control an organism’s interactions with *B*. Representations for Gallistel thus involve ‘functioning’ homomorphisms.

But again, circadian clocks in plants seem to qualify as representations in this sense. They embody the same abstract structure as the day–night cycle, this structural homomorphism is sustained by various cues that carry information about the day–night cycle, and clocks coordinate various plant activities with the day–night cycle. There’s thus a clear sense in which circadian clocks serve as inner *models* of the day–night cycle. Indeed, Gallistel (1998) himself holds that circadian clocks in the nervous systems of animals are “perhaps the simplest of all the well-documented

⁹ I put ‘day’ in quotes because I am writing not of *actual* daytime, but of *represented* daytime. In the biological literature, this distinction is standardly marked by writing of ‘subjective’ day or night. This underscores the general point that it is difficult if not impossible to explain clock-mediated behavior without positing representational content.

¹⁰ It is not clear that clocks are literally ‘selected’ to play control functions here, but it is not clear that neurons are literally ‘selected’ in the process of animal learning either (Crick 1989; Quartz and Sejnowski 1997). The notion of selection is at best an illustrative metaphor for Dretske. What is *theoretically* important for him is simply the idea that content plays a role in explaining the behavior of individual organisms.

functioning [homomorphisms] between brain processes and the world” (p. 28). But we’ve seen that circadian clocks in plants have essentially the same architecture and play essentially the same role as circadian clocks in animals. The main difference is just that clocks in plants are not localized to specific tissues, but this presumably has little to do with their status *as* representations.

3 Propositions

So it seems that nothing but neurochauvinism would prevent the most mature and influential theories of representation in philosophy and psychology from encompassing circadian clocks in plants. Plant clocks have genuine representational content. But what is the nature of that content? Is it propositional? Are the conditions under which plant clocks represent the world really *correctness* or *truth* conditions? Analogous questions arise in the philosophy of perception. It is widely¹¹ agreed that phenomena like illusion and hallucination provide decisive reasons to think that perceptual states have representational content, and it is widely assumed that this content is propositional in nature. An influential line of thought goes like this: When it appears to you that one line of the Müller-Lyer illusion is longer than the other when they are in fact the same length, it is natural to suppose that your experience represents the world in a way it is not, and hence represents the world *incorrectly*. This hardly seems intelligible unless it is also supposed that ordinary, non-illusory perception represents the world correctly. Yet the bearers of correctness and incorrectness are standardly held to be propositions.

A defense of the view that perception has representational (let alone specifically propositional) content is well beyond the scope of this paper. It is enough for present purposes to observe that there is a default presumption in the philosophy of perception that insofar as perceptual experience is representational, it has correctness conditions and hence propositional content. According to Byrne (2004), representationalists about perception generally agree that “perceiving is very much like a traditional propositional attitude, such as believing or intending... when one has a perceptual experience, one bears the perception relation to a certain proposition” (p. 245). Whatever justifies the widespread assumption that the content of perception is *ipso facto* propositional would presumably also justify the view that circadian content is propositional. This assumption seems to be based entirely on the presumed *representational* nature of perception, not on any distinctively *perceptual* features. So the view that circadian clocks have propositional content presumably ought to be the default view, just as it is in the case of perception.

Certainly the view that perception (let alone circadian clocks) has propositional content would have once struck many philosophers as dubious if not absurd. For much of the 20th century, philosophers generally assumed that to grasp a proposition, one must grasp the concepts from which the proposition was presumed to be composed. But Evans’ (1982) influential discussions of the nonconceptuality of

¹¹ Though not universally. See, for example, Brewer (2006) and Travis (2004).

perceptual experience did much to dislodge this entrenched view. Evans argued that perceptual experience can represent the world with a richness of detail that outstrips our conceptual capacities. For example, you might see an apple as being a specific shade of green, and thus have an experience with a specific correctness condition, even if you lack a concept of that particular shade that you can generally exercise in thought.

Evans wrote of the ‘nonconceptual content’ of perception, but this expression is apt to mislead. It suggests that perception has a *kind* of content that differs from the propositional content that is paradigmatically grasped in thought or expressed by declarative sentences. While Evans seems to have in fact endorsed this view, it is not required or entailed by his argument from the richness of perception (Heck 2000). If sound, that argument simply shows that perceptual *states* are nonconceptual, in the sense that a subject can occupy a perceptual state with a content *P* even if she lacks the concepts needed to grasp *P* in thought. This leaves open the possibility that the *content* of perception and thought are fundamentally of the same metaphysical kind, viz. *propositional*.

This possibility is made plausible by a family of views about the metaphysics of propositions that gained prominence in the late 20th century. On these views, propositions *just are* sets of possible conditions under which a representation is correct, or perhaps functions from these conditions to truth values (Montague 1969; Stalnaker 1978). Propositions on these views are said to be *unstructured* since they do not have components corresponding to the logical forms of the sentences used to express them, as traditional Fregean or Russellian views would have it. Evans himself held a Fregean view of the propositional content of thought, which is presumably why he took the richness of perceptual experience to show that perception has a distinctive kind of ‘nonconceptual’ content. But if we grant the cogency of unstructured propositions, as many philosophers now do, we are free to hold with Stalnaker (1998) that *all* content is both nonconceptual and propositional; it’s just that the format of some representational vehicles, such as thoughts, is such that their content can only be grasped by exercising concepts.

Parsimony presumably favors the Stalnakerian view that all content is unstructured ‘possible worlds’ content, and *a fortiori* that perceptual and circadian content is propositional. But even if, like Evans, one took the richness argument to show that perception and thought have metaphysically distinct kinds of content, one needn’t locate that difference in propositionality. Indeed, the richness argument seems to *presuppose* that perception has propositional content. On standard ways of expressing the argument, it purports to show that a subject can enjoy perceptual content *P* even if she lacks the concepts needed to grasp *P* in thought. This presupposes that the contents are metaphysically *the same*, or at least commensurate at some appropriate level of abstraction. But being commensurate or ‘shareable’ in this way is of course one of the core job descriptions for being a proposition. Since thought on prevailing views is propositional if anything is, perception is propositional too.

I don’t take these considerations to be decisive. It is enough for my purposes to observe that on mature, mainstream philosophical views of propositional content, it is uncontroversial that propositional content can be had by all sorts of conceptless systems. In contemporary philosophy of perception there is in fact a widespread

presumption that insofar as perception has content, that content is propositional. Whatever justifies this presumption presumably also justifies the view that circadian representation is *ipso facto* propositional.

One objection to the idea that circadian representation is propositional we can dispense with quickly is that the putative content of the current state of a circadian clock is too *vague* to fix the correctness conditions corresponding to a determinate proposition. After all, a circadian clock is a noisy biochemical process, which only corresponds to the current phase of the day–night cycle within broad and fuzzy boundaries. But paradigmatically propositional entities like beliefs or declarative sentences can also be vague, yet as far I’m aware nobody takes this to show that these entities lack propositional content. Assuming that one of the many extant technical theories of vagueness can accommodate the vagueness of beliefs or sentences (Sorensen 2016), I see no reason why such a theory couldn’t also accommodate the vagueness of circadian clocks.

A more substantive worry is that the ‘fuzziness’ of circadian clocks shows not so much that their content is *vague*, but that it comes in *degrees*. Crane (2009) develops an argument along these lines for the case of perceptual experience, but we might just as well adapt his argument for the case of circadian clocks. Crane allows that perception has content, but denies the default view that this content is propositional. He suggests we might find an alternative view by considering the representational properties of pictures. It seems odd to say that the content of a picture is either true or false; pictorial content rather seems to come in degrees.¹² On this basis, Crane holds that pictures and perceptual states have a kind of content that involves continuous *accuracy* conditions rather than binary truth conditions. Since an essential feature of propositions is the possession of truth conditions, Crane holds that pictures have non-propositional content. *Mutatis mutandis* for circadian content.

But while it might sound odd to some ears to say that a picture is true or false, it perhaps sounds less odd to say that a specific *aspect* of a picture is correct or incorrect. I find nothing linguistically perverse in saying that the *Mona Lisa* is an accurate depiction of Lisa Gherardini except that it represents some aspect of her mouth *incorrectly*. The idea that pictorial content is propositional might suggest the view that the content of the *Mona Lisa* is something silly like ‘The woman is half-smiling’. But of course the propositionalist allows that the content of a picture could be something far richer, subtler, or multifaceted than the content of a simple declarative sentence. The core of her view is simply that although pictures might be accurate or inaccurate, they are (in)accurate with respect to *some specific state of affairs*, and they might get that state of affairs *wrong*. Suppose the lips as depicted by the *Mona Lisa* are slightly wider relative to the rest of the face than Gherardini’s lips in fact were. This is one way in which the painting might

¹² Note that when I write of ‘pictures’ and ‘pictorial content’ here, I specifically have in mind the *representational* features of pictures. Not all pictures are representational in the sense that they purport to depict some specific state of affairs, and even those that are might be said to have a kind of *non-representational* expressive or affective content. Like Crane, I focus only on the representational features of pictures.

get things wrong. We can of course imagine other possible paintings that depict the lips as being slightly wider or narrower, fuller or thinner, across various different continuous dimensions. It is in this way that a picture might be ‘more’ or ‘less’ wrong. But this is a feature of the *format* of pictures, not of their content. Crane’s objection to the propositionality of pictures thus seems to rest on a subtle vehicle-content confusion wrapped up in an uncharitable interpretation of its target.

These observations can be turned directly against the view that pictures have non-propositional content. It seems plausible that the content of a picture could in principle be expressed by a (perhaps very long and complicated) declarative sentence in some language or other, a sentence with propositional content that captures the correctness conditions of the picture. To suppose otherwise would be to suppose that there are certain aspects of pictorial content that are fundamentally ineffable and forever beyond the reach of any possible linguistic expression. This might be true, but it is a very strong claim that presumably stands in need of substantial justification.

Crane anticipates this objection to his non-propositional view. He concedes that pictorial content is *not* ineffable, and indeed grants that the following principle (P) is “undeniable” (p. 460):

P. For any picture *P*, there is a sentence which gives the content of *P*.

However, Crane replies that the mere fact that a sentence can ‘give’, i.e., *describe*, the content of a picture doesn’t entail that the picture *has* propositional content, since “describing the content and *being* the content are not the same thing” (p. 460). This is obviously true, but beside the point. No one would wittingly hold on the basis of (P) that a sentence that ‘gives’ the content of a picture is numerically *identical* to that content; that would rest on an egregious vehicle-content confusion. On the most straightforward and plausible reading of (P), the term ‘give’ simply denotes the relation that a representational vehicle stands to its content. A more neutral term for this relation might be ‘express’. Reformulating (P) thusly so as to keep the distinction between vehicle and content clearly in view, we get principle (P’):

P’. For any picture *P* that expresses content *C*, there is a sentence that also expresses *C*.

This principle entails that the content of any picture is the same as that of some declarative sentence. Since its common ground that declarative sentences have propositional content, (P’) entails that pictorial content is propositional.

It’s unclear whether Crane (2009) would endorse (P’). While he explicitly holds that he’s using ‘give’ to refer specifically to the *description* relation (p. 460), which would involve no commitment to (P’), he elsewhere he seems to treat ‘give’, ‘express’ and ‘describe’ as synonyms that refer broadly to whatever relation a representation stands to its content (p. 454). Indeed, he explicitly takes (P) to be equivalent to the thesis that for any picture, there is “a sentence that has the *same* content as the content of the picture” (p. 460), which is equivalent to (P’).

But whether or not Crane endorses (P'), it is this principle that he must reject if he is to deny that pictorial content is propositional, for it is this principle that entails (given presently shared assumptions) that pictures have propositional content. To deny this principle, one must insist that some pictures have content that could not *in principle* be expressed by any possible sentence: that pictorial content is *ineffable*. Crane himself agrees that this is a very strong claim, and when we penetrate the clouds of vehicle-content confusion we see that he provides no reason at all to believe it. So there's every reason to think that pictures have propositional content.¹³ All the same points apply, *mutatis mutandis*, to circadian clocks.

4 Attitudes

The upshot of the preceding sections is that on certain plausible mainstream views in philosophy, circadian clocks in plants qualify as representations with propositional content. But why does this pose a problem for the traditional view that propositional representations are constitutively related to the cognitive, inferential capacities of rational agents? After all, *sentences* are paradigmatically propositional representations, yet they are not cognitive states, and nobody takes *that* to pose a problem for the traditional view. The crucial point, of course, is that circadian clocks help organisms get by in the world by virtue of representing it; they function as representations *for the organism*, and aren't just representations because they are interpreted as such; they are representations with *underived* propositional content. This was the central point of Sect. 2, but it's important to revisit the point here, since it directly bears on the question of why circadian clocks are not merely propositional *states*, but genuine propositional *attitudes*.

According to dominant views in philosophy of mind since the 1970s, propositional attitudes are underived propositional representations that play a distinctive functional role (Fodor 1987a). Different types of propositional attitudes are thought to be individuated by different functional roles. I know of no systematic attempt to answer the question of precisely what role propositional representations must play in order for them to qualify as attitudes. Rather, the functional roles that are thought to individuate specific attitude types are typically discussed on a case-by-case basis. Beliefs, for example, are widely said to play something like the following role: they (1) respond appropriately to sensory evidence, (2) mediate learning processes, (3) are integrated with other information in decision-making, and so forth. Nobody has every spelled at the 'so forth', but it seems to me that most mainstream intentional realists in the philosophy of mind would agree that any underived propositional representation that plays something like the functional role I just sketched would at least qualify as a *belief-like* propositional attitude.

¹³ Crane has an independent line of argument against the propositional view of pictorial content, based on the idea that pictures do not stand in the logical relations that propositions necessarily do. Grzankowski (2015) ably shows that this rests on another vehicle-content confusion, so I needn't engage with this argument here.

I'll now argue that circadian clocks in plants play just such a role. I already laid the argumentative groundwork for this claim in Sect. 2, where I argued that plant circadian clocks have underived representational content because they satisfy the 'use' condition central to mature, mainstream theories of representation. Circadian clocks serve to control various activities in plants, like anticipatory leaf reorientation. They can do so successfully because they function to track the property in the world that successful reorientation depends on: the phase of the day–night cycle. In virtue of this, their content has a 'state-to-world' or *thetic* direction of fit that is widely thought to partly individuate belief-like attitudes (Searle 1983).¹⁴ The job of a circadian clock is to reflect *that* the world is a particular way. This content is not merely available to be interpreted by intrepid chronobiologists, it plays a crucial role in explaining why plants behave the way they do. If plant clocks didn't accurately reflect the day–night cycle, plants would shrivel and be eaten.

Further, the world-directedness of plant circadian clocks is manifested in at least three functional roles that are distinctive of belief-like attitudes. First, clock entrainment is mediated by mechanisms that allow clocks to respond appropriately to sensory *evidence*. The oscillatory phase of a circadian clock is not directly tied to the vicissitudes of environmental stimuli; rather, various filtering and gating mechanisms help to ensure that clocks reliably reflect the day–night cycle. For example, stimuli are only effective at advancing or delaying the phase of a clock if they are appropriately integrated, or if they occur at specific times, or if they persist for sufficiently long durations (Gardner et al. 2006). These mechanisms are thought to prevent nuisance variables like moonlight or flashes of lighting from updating the clock, and indeed theoretical work suggests that they ensure a mathematically optimal balance between plasticity and stability conducive to accurate and reliable updating (Hasegawa and Arita 2014).

Second, we've already seen that circadian clocks seem to mediate *learning* in plants. Gagliano et al. (2016) provide evidence that plants can be conditioned to respond to neutral stimuli like wind, and that this process is gated by circadian clocks. As the authors point out, this makes adaptive sense, for allowing flexible light foraging to occur when the sun isn't present would incur a significant metabolic cost.

Third, circadian clocks in plants seem to mediate recognizably *decision-like* processes. For example, I noted earlier that plant leaves contain phytochromes that respond to red light. Such light is reflected by the leaves of neighboring plants due

¹⁴ One might also hold that plant clocks play a desire-like, *telic* role since they serve to guide the plant's activities. In that case they would qualify as what Millikan (1995) calls 'pushmi-pullyu' representations. I am not primarily concerned in this paper to identify precisely what *kind* of attitudinal role plant circadian clocks play; my main goal is just to show that they play *some such role or other*. I should note that nothing I say here provides reason to think plants can have several different kinds of attitude. Interpretivists would reject 'punctate' propositional attitudes on grounds that attitude ascription is necessarily holistic (Davidson 1973), but I think most of the realists I am engaging with here would admit the possibility of punctate attitudes. Still, some might deny this. As I'll go on to discuss shortly, realists might invoke various reasons for resisting the conclusion that plants have genuine attitudes—but in doing so they're bound to make assumptions that other realists would find deeply implausible.

to the absorbance profile of chlorophyll. Some plants can detect when their neighbors are encroaching and potentially blocking out sunlight via increasing levels of phytochrome signaling, and will produce a rapid elongation of their stems and leaves in response. Salter et al. (2003) show that this ‘shade avoidance response’ is not reflexively *triggered* by phytochrome activity, but is regulated by the plant’s circadian clock: the response primarily occurs only when the clock represents that it is dusk (Yakir et al. 2007). This is just one example of how circadian rhythms are integrated with other signals so as to regulate a plant’s activities in virtue of the *content* of those signals. If analogous processes occurred in an animal’s brain, many cognitive scientists would be inclined to regard them as *decisions*.

So it seems that circadian clocks in plants play the kind of functional role that is commonly thought to individuate belief-like attitudes. But since there is no canonical characterization of the functional role that constitutes belief or any other propositional attitude, there is room for someone who opposes the view that plants have propositional attitudes to insist that there is some further feature that distinguishes genuine attitudes from propositional states in plants. I now consider two general directions that such a traditionalist might explore.

We might first consider a traditional way of picking out the propositional attitudes stemming from Chisholm’s (1955) influential ‘linguistic criterion’ for demarcating psychological from non-psychological phenomena. Chisholm held that a sentence *S* reports a psychological phenomenon just in case *S* satisfies either of the following conditions: (1) *S* contains a singular term but does not entail the existential generalization relative to that term, or (2) *S* contains a singular term that if replaced with a co-referring term alters the truth-value of *S*.¹⁵ A sentence that satisfies either condition is said to be *intensional*. While Chisholm himself held that intensionality is the mark of the *psychological*, not of propositional attitudes per se, his linguistic criterion has traditionally been taken to limn the class of propositional attitudes. Ascriptions of content to circadian clocks in plants arguably do *not* involve intensional contexts, so by this traditional criterion plant clocks would not qualify as propositional attitudes.

However the linguistic criterion of propositional attitudes is no longer widely endorsed. One reason is that many intensional sentences report phenomena that are uncontroversially non-psychological. To adapt Quine’s classic example, consider the following true sentence (S1):

S1. It is contingent that the number of planets in the solar system is eight.

Replacing “the number of planets” with the co-referring expression “eight”, we get a sentence that is no longer true. Thus (S1) is intensional, yet it doesn’t report a propositional attitude or any other psychological phenomenon. A proponent of the linguistic criterion might retrench to the view that the linguistic criterion is not necessary *and* sufficient condition for the presence of propositional attitudes, but merely necessary. That’s enough to make trouble for the ascription of propositional attitudes

¹⁵ Chisholm appealed to a third criterion, but this is not relevant for my purposes so I leave it out for the sake of expository clarity.

to plants. But if the linguistic criterion is no longer held to demarcate all and only propositional attitudes, it's no longer clear why we should think that attitude reports are necessarily intensional. Why not think that intensionality is merely an *indicator* of certain cognitively sophisticated attitudes, rather than being an infallible guide to the essential nature of the attitudes?

In any case, these issues are arguably moot, since it's not obvious that reports of circadian content really do fail to be intensional. If what I've said so far is right, the following sentence might in some contexts be true: "The circadian clock in plant *P* represents that the sun is at phase ϕ of the day–night cycle". Consider the unlikely but presumably possible scenario in which the sun no longer exists (suppose a rampant intergalactic artificial intelligence destroys the sun but preserves the Earth and its vegetal inhabitants to make a philosophical point). In that case, there would be no sun to make the existential generalization of the sentence true, so the sentence would qualify as intensional after all. Whether this is plausible depends on a variety of complicated issues, such as whether we should think that the sun per se might be included in circadian content. Beyond arguing *that* circadian clocks have propositional content, I remain neutral on the question of exactly that content ought to be characterized. I'll simply note that on mainstream externalist theories of content there would seem to be nothing problematic about the view that the sun might be included in circadian content. That is, after all, what clocks have the function of tracking.

A second strategy for arguing that propositional representations in plants are not genuine attitudes is to insist that attitudes are individuated by functional roles that are far more flexible or reason-responsive than the forms of 'learning' and 'decision-making' discussed earlier. One might insist that these are not genuine learning or decision-making processes at all, or at least that they're not sufficiently rational forms of these processes to individuate genuinely belief-like attitudes. Alternatively, one might appeal to various other sophisticated cognitive capacities to distinguish genuine attitudes from mere propositional representations, such as capacities to grasp concepts, engage in reasoned inference, or understand language.

I have three points to make about this line of argument. The first is that the 'sophisticated' cognitive capacities that might be taken to distinguish genuine attitudes from mere propositional representations are standardly characterized *in terms* of propositional attitudes. For example, dominant views of inference in the literature hold that inference consists in causal relations between propositional attitudes that 'respect' semantic relations between those attitudes (Fodor 1987a, b). The order of explanation is generally assumed to proceed from propositional attitudes to cognitively sophisticated capacities, not the other way round. So to deny that plants have propositional attitudes on grounds that they lack sophisticated cognitive capacities would beg the present question. Prevailing methodology would have us *first* ask whether plants have propositional attitudes, *then* ask whether those attitudes, say, participate in inferential relations. The clocks distributed throughout a plant's tissues

in fact seem to causally influence each other so as collectively keep time (Gardner et al. 2006), and presumably do so *in virtue* of the time that each individual clock represents, so there's reason to think that plants actually do engage in inference as standardly construed.¹⁶

Second, I have no doubt that some non-question-begging characterization of 'sophisticated' cognitive capacities like inference or decision-making could be given that would distinguish intelligent agents like us from merely reactive systems like plants. I happen to think that we and other animals have minds, whereas plants do not, and that it is the job of the cognitive sciences to illuminate the various capacities that mark this undoubtedly fuzzy but real distinction. But the question at issue here is what *any of this has to do with propositional attitudes*. Appealing to rational cognitive capacities only helps to draw the distinction between systems that have propositional attitudes and systems that don't if one antecedently assumes that propositional attitudes are constitutively connected to those capacities. But that's precisely what's in question. It's unclear what principled, independent reasons there are for endorsing this view.

The third and final point is this. In addressing objections to the view that circadian clocks in plants qualify as propositional attitudes, I have raised some problems with these objections, but I don't claim to have provided conclusive replies. For all I've said one might well be able to identify some principled reason for denying that plant circadian clocks are propositional attitudes. But in doing so one would inevitably commit oneself to controversial philosophical views about the nature of representation, propositions, or attitudes. For example, one might insist that genuine propositional attitudes are only had by creatures that can reflect on propositional contents as objective reasons for thought or action (Davidson 1982; McDowell 1994). This would seem to imply that not only plants but also most animals including many humans lack propositional attitudes, a view that most philosophers and psychologists would likely find radically implausible.

So what's the problem? Aren't all substantive philosophical views controversial to *someone*? It is important here to recall the conditional thesis of this paper: *if* certain reasonable, mainstream theories of propositions and attitudes are correct, *then* circadian clocks in plants count as propositional attitudes. The putative objections we've considered are not objections to this thesis, they are simply ways of denying the consequent so as to use the thesis in a *reductio* of its antecedent. I do not deny that one might reasonably do this. My point is just that in doing so, one must shoulder considerable philosophical burdens. The view that plants lack propositional attitudes can no longer be taken for granted. On some mainstream realist views, propositional attitudes are the mark of rarefied reflective thought, while on other such views *all sorts* of putatively mindless systems might have attitudes. Yet this radical divergence seems to be largely unnoticed. The purpose of this paper was to call attention to the divergence, and to urge that if philosophers or psychologists are

¹⁶ I remain officially neutral on the question of whether this implies that capacities like inference are ubiquitous in nature, or that standard views of such capacities are empirically inadequate. I happen to believe the latter, but this biographical fact is irrelevant to the conditional thesis of this paper.

to invoke propositional attitudes in their theorizing about psychological phenomena, they explain precisely which theories of representation, propositions, and attitudes they're assuming.

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