The Sphex story

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The *Sphex* story: How the cognitive sciences kept repeating an old and questionable anecdote

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The Sphex story is an anecdote about a female digger wasp that at first sight seems to act quite intelligently, but subsequently is shown to be a mere automaton that can be made to repeat herself endlessly. Dennett and Hofstadter made this story well known and widely influential within the cognitive sciences where it is regularly used as evidence that insect behavior is highly rigid. The present paper discusses the origin and subsequent empirical investigation of the repetition reported in the Sphex story. The repetition was first observed by Henri Fabre in 1879 and the last empirical study I did find was published in 1985. In contrast to the story's clear message, the actual results have always been equivocal: the endless repetition is not standard. In addition, this repetition itself has become a minor aside in the literature on digger wasps when put in the perspective of many other examples of adaptiveness and flexibility. Nevertheless, the story and its message have to this day persevered within the cognitive sciences. For some reason, the counterevidence has been neglected time and again. The paper closes by presenting two different but compatible hypotheses that could explain why humans keep repeating this particular anecdote.

Within the cognitive sciences, insects are generally viewed as having very limited cognitive powers: Insects do of course behave in ways that may seem to involve reasoning and intelligence. However, on closer acquaintance, such behavior turns out to be extremely mechanistic. This general attitude toward the behavior of insects and other invertebrates has become perfectly exemplified as well as amplified by the widely dispersed *Sphex* story. Here is the version that became a classic of cognitive science, originally stemming from Wooldridge, but later repeatedly used by Dennett, Hofstadter and many others.

> When the time comes for egg laying, the wasp *Sphex* builds a burrow for the purpose and seeks a cricket which she stings in such a way as to paralyze but not kill it. She drags the cricket into the burrow, lays her eggs alongside, closes the burrow, then flies away, never to return. In due course, the eggs hatch and the wasp grubs feed off the paralyzed cricket, which has not decayed, having been kept in the wasp equivalent of a deepfreeze. To the human mind, such an elaborately organized and seemingly purposeful routine conveys a convincing flavor of logic and thoughtfulness—until more details are examined. For example, the wasp's routine is to bring the paralyzed cricket to the burrow, leave it on the threshold, go inside to see that all is well, emerge, and then drag the cricket in. If, while the wasp is inside making her preliminary inspection, the cricket is moved a few inches away, the wasp, on emerging from the burrow, will bring the cricket back to the threshold, but not inside, and will then repeat the preparatory procedure of entering the burrow to see that everything is all right. If again the cricket is removed a few inches while the wasp is inside, once again the wasp will move the cricket up to the threshold and re-enter the burrow for a final check. The wasp never thinks of pulling the cricket straight in. On one occasion this procedure was repeated forty times, always with the same result. (Wooldridge, 1963, pp. 82-83)

The message is clear and simple. Behavior that seems to be strikingly intelligent is actually the result of a straightforward mechanical setup that involves a strict and rigid sequencing of environmental triggers to regulate the several steps involved. The insect is not at all aware of what it is doing and its internal processes are in this sense very different from the characteristics of human cognition. Hofstadter even coined the term '*sphexish'* to refer to such an unknowing and mechanical form of 'seeming intelligence,' and set it as the "totally opposite to what we feel *we* are all about, particularly when we talk about our own consciousness" (1985, p. 529). Dennett used this notion to refer to the possibility that we might be sphexish ourselves, only less obviously so, and investigated possible implications for free will. The general idea here is that, if this rigidity of behavior is true for insects as a fundamental property that can be uncovered under the right circumstances, then the same should apply to the more complex but not intrinsically different case of human beings.

In this paper, I will sketch the history of the *Sphex* story, focusing on what I will call the *cricket test* as described in the quote. This test and the resulting 'endless' repeat can be traced back to the work of Henri Fabre, who first reported this finding in 1879. Since then this particular behavior has been studied repeatedly by other students of insect behavior. They performed the cricket test on various species of digger wasp, such as *Sphex* species, but also *Ammophila* species that prey mostly on caterpillars. Looking at this history, there are several striking features. First and foremost, digger wasps *very often do not repeat themselves endlessly* when the cricket test is done. After a few trials many wasps take the cricket into their burrow without the visit. Second, in certain cases there are ecological and practical reasons for repeating the visit. Third, the cricket test focuses on an extremely minor component of digger wasp behavior, which has since its discovery been completely swamped by many other findings that provide a very different general picture of the mind of the digger wasp. Finally, it is very striking that the equivocal results of the cricket test have been and still are systematically ignored or downplayed. The factual findings seem to have less impact than the clear-cut but fanciful mechanistic image the story evokes.

The *Sphex* story does not tell us much about digger wasps. But the human repetition of the story over such a long period should teach us something important about our own tendencies when it comes to the interpretation of basic forms of behavior. I will give two mutually supportive hypotheses that may help explain why it is so difficult for us not to repeat this anecdote. At a theoretical level, the *Sphex* story is useful to argue both for and against the presence of deep differences between the human mind and the intelligence of insect-like animals. In addition, the story seems so striking because it plays on the general human capacity to differentiate agents from non-agents in an automatic way. The second hypothesis in particular, provides an explanation why the story is so catchy and seems to convey a special insight, as stressed by Hofstadter.

1 The Sphex story's dispersal in cognitive science

The *Sphex* story has been widely dispersed within the cognitive sciences, spreading the message that insect intelligence is very basic and mechanical. This dispersal was achieved mainly through the efforts of Douglas Hofstadter and Daniel Dennett. In 1982, Hofstadter gave the story a wide hearing when he quoted Wooldridge in his mathematical column in *Scientific American* (republished in Hofstadter, 1985), calling it "One of my favorite passages" (1985, p. 529). Dennett quoted Wooldridge for the first time in 1973 as an example of a mechanistic explanation which did not involve an intentional explanation (p.171). This paper was reprinted in *Brainstorms* (Dennett, 1978), where the full quote was skipped as it already appeared in a different paper in the same volume. In his 1984 book *Elbow Room*, Dennett gives a lot of prominence to the *Sphex* story. He quotes Wooldridge (1963) again in full and then uses Hofstadter's notion of sphexishness to describe one of our major fears when it comes to free will: We may ourselves be sphexish and only seemingly free agents, just like the poor wasp in the story. The story and ‘sphexish’ occur repeatedly after this introduction. The same Wooldridge quote occurs yet again in Dennett (1998), in a reprint of his 1984 paper *Cognitive wheels: The frame problem in AI*. Dennett still referred to the story in his book *Freedom Evolves* where it is mentioned in passing as an established fact:

> In these models, the individual organisms are stipulated to be old dogs that can’t learn new tricks and are stuck as lifetime cooperators or defectors. […] This is not much of an oversimplification if you’re dealing with insects, whose behavioral routines are relatively rigid and tropistic (or *sphexish*, to use the term Douglas Hofstadter coined in honor of the *Sphex* wasp). (Dennett, 2003, p. 198)

Thus Dennett has used or referred to the *Sphex* story repeatedly over a period of 30 years, making the story widely available within the cognitive science community.

The clear message and its wide dispersal by Dennett and Hofstadter has resulted in the story popping up far and wide as a factual statement that unmasks unwarranted assumptions concerning insect intelligence and that underpins the ‘fact’ of the rigidity of insect behavior. In 2009, googling ‘Sphex’ combined with ‘Dennett’ or ‘Hofstadter’ gave 967 pages (August 13), including the following description in Wikipedia:

> This iteration can be repeated again and again, with the *Sphex* never seeming to notice what is going on, never able to escape from its programmed sequence of behaviors. Dennett's argument quotes an account of *Sphex* behavior from Wooldridge's *Machinery of the Brain* (1963). Douglas Hofstadter and Daniel Dennett have used this mechanistic behavior as an example of how seemingly thoughtful behavior can actually be quite mindless, the opposite of free will (or, as Hofstadter described it, *antisphexishness*).

This same text is repeated on many other places on the web when one searches for wasps. In addition, the story occurs in many published works within the cognitive sciences and the philosophy of cognition (e.g. Brooks, 2002; Carruthers, 2004; Double, 1988; Elton, 2003; Fogel, 2000; Franklin, 1995; Millikan, 2004; Newen & Bartels, 2007; Newman, 2001; Stephan, 1999; Sterelny, 1990).

To rub in how the *Sphex* story has shaped the minds of many workers within the cognitive sciences, here are some conclusions phrased by some of these authors. Sterelny (1990. p. 20) says: "Sphex has a single, invariable behaviour pattern. … Wasps aren't very thoughtful." Fogel (2000, p. 284) notes: "nothing more than an automatic reflex, genetically hardcoded behavior. It's just like a calculator that adds 10 plus 10." Millikan (2004, p. 169) writes: "The wasp seems not to understand the purpose of its own activity so as to know when that purpose has been accomplished." Stephan (1999, pp. 83-84) remarks: "Even among philosophers, sphex has become famous through a number of articles by Daniel Dennett." and "spheges appear dim-witted within the unnatural experimental setting . Neither do they mind nor do they remember – there is no learning." Carruthers (2004) states: "The wasp appears to have no conception of the overall goal of the sequence, nor any beliefs about the respective contributions made by the different elements." Finally, Elton (2003, p. 135) claims that: "All Sphex wasps can be caught out by the experimenter who moves the cricket away from the burrow entrances." In all cases the story is accepted without questioning and considered to represent a general fact about the behavior of *Sphex* wasps.

All in all, one can conclude that the *Sphex* story has become part and parcel of the general knowledge of the cognitive science community, and has been an important factor in shaping the views of many researchers concerning the presumed rigidity of insect intelligence. Intriguingly, within the cognitive sciences neither the story, nor its message has been seriously investigated. Its truth is taken at face value with always the same single quote from Wooldridge as its source. However, given the wide influence of the *Sphex* story, it is important to check its credentials and establish whether it really tells us something important about these wasps, leave alone insects in general.

2 Moving through the Wooldridge barrier

As everyone within the cognitive sciences refers directly or indirectly to Wooldridge as its source, the first question is: Where did Dean Wooldridge pick up the story? Wooldridge was not a biologist, nor in any other way involved in the study of insects. He had a background in engineering, co-founded the aerospace technology Ramo-Wooldridge Corporation in 1953, and from 1962 onward devoted himself to scientific pursuits and writing. *The Machinery of the Brain* was a first result and an attempt to provide a readable introduction to some of the then recent developments in brain research (Wooldridge, 1963, p. i). In contrast to Dennett, Hofstadter refers to another book by the same Wooldridge (1968, p. 70). However, the key quote is identical in both cases, except for three minor textual changes. Wooldridge (1963) doesn't explicitly say from which source he took the *Sphex* story. However, at the end of the relevant chapter he gives a general list of references, and in one of these the story can be found: the huge, two volume book *The Science of Life* written by H.G. Wells, Julian Huxley and G.P. Wells. This is what they say:

> The instinctive and machine-like quality of most of their behaviour was clearly shown by some experiments of Fabre on the wasp Sphex, which hunts crickets. When the Sphex has brought a paralyzed cricket to her burrow, she leaves it on the threshold, goes inside for a moment, apparently to see that all is well, emerges, and drags the cricket in. While the wasp was inside, Fabre moved the cricket a few inches away. The wasp came out, fetched the cricket back to the threshold, and went inside again—on which Fabre moved again the cricket away. He repeated the procedure forty times,

> always with the same result; the wasp never thought of pulling the cricket straight in. Drag cricket to the threshold—pop in—pop out—pull cricket in: the sequence of actions seems to be like a set of cog-wheels, each arranged to set the next one going, but permitting of no variation. (Wells, Huxley & Wells, 1931, p. 1161)

This is exactly the story that is retold later by Wooldridge and which has resulted in the familiar picture of the mechanistic character of the wasp's behavior, but now with the name of Fabre included as the originator of the story. However, and remarkably, this same paragraph goes on without any interruption and ends in the following way:

> The Peckhams repeated the experiment with an American Sphex. This creature was not quite so automatic, for after her prey had been moved a number of times, she did drag it straight into her burrow. (ibid.)

Thus, not only the *Sphex* story is present in Wooldridge's source, but so is a later trial with the cricket test with the opposite result. The claim concerning the extreme rigidity of *Sphex* has already been challenged and disconfirmed by someone else.

Both Fabre and the Peckhams are well-known for their studies of insect behavior in the late nineteenth and early twentieth century. I will discuss their work at some length to get a grasp of the facts that gave rise to their respective claims. However, before turning to them, it is important to articulate how Wooldridge's treatment of the *Sphex* story encouraged its later dispersal within cognitive science. First, he turned the story into the unequivocal message that all sphexes behave in this particular way, a message that was not present in his source text that did mention the Peckhams' different result. Second, he brought the story that was already well-known among naturalists to the attention of a new type of reader, those working in fields like control theory, engineering neural circuits and what became eventually the cognitive and computational neurosciences. This audience would know very little about insect behavior and would not be inclined to read up on this story or do further investigations.

Third, he left out Fabre's name, which not only robbed Fabre of the credit he deserves for devising the cricket test, but which also made the story more difficult to trace and check, in particular for his cognitive science audience who generally would never have heard of Fabre or the Peckhams.

With this, all was set to launch the catchy *Sphex* story to its current influence within the cognitive sciences. The idea of an endlessly repeating behavior was very suggestive of a computational subroutine and a clear target for a computational explanation.

> To the computer scientist, there must be a sense of familiarity to this type of behavior. It has the earmarks of a set of subroutines recorded in the permanent memory system of a computer and called into play by the appearance of certain conditions of the input data. (Wooldridge, 1963, p. 83)

The message of an endless repeat made it possible to draw a clear link between insect behavior and computational procedures. Wooldridge used this link between computational procedures and the organizing principles behind animal behavior as a foothold for a fully mechanistic approach of the human brain: Intelligence, including human intelligence, can be produced by mechanical—that is computational—means. In this tendency he was later followed by Hofstadter and Dennett, and many others in cognitive science.

3 Fabre's original experiment and later findings

Henri Fabre (1823-1915) was an important French field biologist and science writer, "whose life-long study of the insects remains a marvel of indefatigable labor and detailed observation." (Warden, 1927, p. 148), and who Charles Darwin referred to as the "inimitable observer" (Pasteur, 1994). Fabre in turn was a staunch anti-Darwinian who believed that God created each species and its behavior, and who used his studies to argue against the idea that evolution had taken place. From his early retirement around 1871 until his death in 1915 Fabre devoted all his time to writing, observing nature and experimenting with insects (Pasteur, 1994). This research resulted in a series of essays eventually constituting the ten volumes of his widely read *Souvenirs Entomologiques*, published between 1879 and 1904. The *Sphex* story can be found in the first volume of the *Souvenirs*, in a chapter dedicated to the yellow-winged *Sphex* or *Sphex flavipennis*, as Fabre calls it. The relevant essay is translated in *The Hunting Wasps*, a book first published in 1915 that is still in press today (Fabre, 1915/2001).

> I will mention an experiment which interested me greatly. Here are the particulars: at the moment when the Sphex is making her domiciliary visit, I take the Cricket left at the entrance to the dwelling and place her a few inches farther away. The Sphex comes up, utters her usual cry, looks here and there in astonishment and, seeing the game too far off, comes out of her hole to seize it and bring it back to its right place. Having done this, she goes down again, but alone. I play the same trick upon her; and the Sphex has the same disappointment on her arrival at the entrance. The victim is once more dragged back to the edge of the hole, but the Wasp always goes down alone; and this goes on as long as my patience is not exhausted. Time after time, forty times over, did I repeat the same experiment on the same Wasp; her persistence vanquished mine and her tactics never varied. (Fabre, 1915/2001, p. 43)

All familiar ingredients are present, up to the tell tale number of forty. However, the text offers some additional surprises. A few lines further Fabre writes the following (bear in mind that these wasps are solitary but still make their separate burrows in colonies, like sea gulls):

> Having demonstrated the same inflexible obstinacy which I have just described in the case of all the Sphex-wasps on whom I cared to experiment in the same colony, I continued to worry my head over it for some time. What I asked myself was this:

> "Does the insect obey a fatal tendency, which no circumstance can ever modify? Are its actions all performed by rule; and has it no power of acquiring the least experience on its own account?" […] good fortune brought me into the presence of another colony of Sphex-wasps, in a district at some distance from the first. I recommenced my attempts. After two or three experiments with results similar to those which I had so often obtained, the Sphex got astride of the Cricket, seized him with her mandibles by the antennae and at once dragged him into the burrow. […] At the other holes, her neighbours likewise, one sooner, another later, discovered my treachery and entered the dwelling with the game, instead of persisting in abandoning it on the threshold to seize it afterwards. […] Next day, in a different locality, I repeated my experiment with another Cricket; and every time the Sphex was hoodwinked. I had come upon a dense-minded tribe, a regular village of Boeotians, as in my first observations. (Fabre, 1915/2001, pp. 43-44)

Remember that this is the original source of the *Sphex* story. Fabre, the inventor of the cricket test, did this test repeatedly with different wasps. But in contrast to the currently popular version his results were equivocal. He reported an indefinite repetition in wasps from certain colonies, but not in wasps of the *same species* from other colonies. Thus, from the very start the actual results were not as clear-cut or universal as the widely circulated story holds.

In another chapter—*Ignorance de l'instinct*—of the same volume, Fabre returns to the behavior described in the *Sphex* story. He discusses here the issue of misfiring instincts, of which the *Sphex* story is but one example. Instincts, he concludes, are perfectly adapted under natural conditions but are incapable of coping with artificial conditions, as induced by a human experimenter (1879, p. 179). In this chapter, he states that his results with the cricket test for another species, *Sphex albisecta*, conform fully to those of the original yellow-winged *Sphex flavipennis* and then draws an interesting conclusion:

> Let us recall here that the Yellow-winged Sphex does not always allow herself to be caught by this trick of pulling away her Cricket. There are picked tribes, strong-minded families which, after a few disappointments, see through the experimenter's wiles and know how to baffle them. But these revolutionaries, fit subjects for progress, are the minority; the remainder, mulish conservatives clinging to the old manners and customs, are the majority, the crowd. (Fabre, 1915/2001, pp. 116-117)

Fabre does not say why he concludes that the indefinite repetition is the normal case, while the smarter wasps are merely an exception. However, this conclusion fits his general view that insect behavior results from instinctive mechanisms and not from any reasoning capacities. In any case, here at the very origin of the *Sphex* story, the available counterevidence is set aside as the aberration.

What subsequently spread out from Fabre's work was the *Sphex* story as we know it today, without reference to his more equivocal results (e.g. Romanes, 1886; Peckham & Peckham, 1898; Morgan, 1900; Wells, Huxley & Wells, 1931), although there are also exceptions (e.g. Bierens de Haan, 1940).

4 The Peckhams' controversy with Fabre

Not everyone did passively accept Fabre's conclusion concerning the *Sphex* story. George and Elizabeth Peckham were two well known American entomologists who worked around 1900. In their preface of *Instincts and Habits of Solitary Wasps* (1898) they state that reading Fabre's *Souvenirs Entomologiques* inspired them to study the solitary wasps, such as *Sphex*, for themselves (1898, p. 1). They explicitly say here that they respect Fabre's work very much, even though their conclusions are markedly different (ibid.). A discussion of the habits of *Ammophila*, a genus of digger wasps with habits similar to those of *Sphex*, illustrates these differences. Fabre claims that their instincts are perfectly adapted and can "never have varied to any appreciable extent from the beginning of time," because any deviation would mean extinction (Peckham & Peckham, 1898, pp. 30; 1905[1], p. 52). To this the Peckhams reply:

> The conclusions that we draw from the study of this genus differ in the most striking manner from those of Fabre. The one preeminent, unmistakable and ever present fact is variability. Variability in every particular—in the shape of the nest and the manner of digging it, in the condition of the nest (whether closed or open) when left temporarily, in the method of stinging the prey, [etc.] (1898, p. 30, 1905, p. 53)

Fabre's account of the *Sphex* must have piqued them, as the implied rigidity and sheer lack of variability is very much contrary to their own Darwinian perspective and general observations of insect behavior.

The Peckhams did their own follow up of the cricket test with an American digger wasp *Sphex ichneumonea*, which preys on grasshoppers. In 1900 they reported their finding in a short two page paper and later in a popular book (Peckham & Peckham, 1905). Here they used these findings as their closing statement. After describing the *Sphex* story—using the same text as in 1898—they describe their own experience with the cricket test:

> On the following day, when she had brought a grasshopper to the entrance of the nest, and while she was below, we moved it back five or six inches. When she came out, she carried it to the same spot and went down as before. We removed it again, with the same result, and the performance was repeated a third and a fourth time, but the fifth time that she had found her prey where we had placed it she seized it by the head, and going backward dragged it down into the nest without pausing. On the next day the experiment was repeated. After we had moved the grasshopper away four times, she carried it into the nest, going head foremost. On the fourth and last day of our

[1] The Peckhams reused portions of their more scholarly 1898 book in their *Wasps, social and solitary*, published in 1905 for a wider audience. Many of the references to the 1898 book can also be found there, which will be indicated by a double reference.

> experiment, she replaced the grasshopper at the door of the nest and ran inside seven times, but then seized it and dragged it in, going backward. (Peckham & Peckham, 1905, pp. 304-305)

Despite a tendency to stick to the standard procedure and to repeat itself, this wasp did modify its behavior after a few trials. Like Fabre’s original story, this opposing finding by the Peckhams also became widely spread in the literature on digger wasps, starting with Lloyd Morgan (1900) and eventually finding its way to the text by Wells, Huxley and Wells (1931) from which Woodridge drew his version.

From here on, the Peckhams became portrayed as the standard antagonists of Fabre: He being the defender of the God-given and eternal fixity of instinct, they the defenders of a Darwinist view who claimed and reported the presence of variability of almost all aspects of insect behavior. For a while, Fabre and the Peckhams were even regularly cited within psychological texts (e.g. Boring, 1921; McDougall, 1928). The fixity of insect behavior was here treated as a matter of discussion, not a matter of fact. The story that was later dispersed in the cognitive sciences took up only one part of this discussion and was ultimately based on the single report of Henri Fabre.

It can be concluded that the scientific foundation for the *Sphex* story as told within the cognitive sciences is extremely weak. However, it is possible that additional studies on the cricket test have settled this matter in a way that generally supports the message of the modern *Sphex* story. Even when those later studies never played any role in establishing the story, they may still support the *Sphex* story’s current standing as a representative account of digger wasp behavior. Therefore an important issue remains: What happened to the cricket test in later studies on animal behavior and what were the results?

5 The *Sphex* story in Baerends classic ethological studies

In the 1930s, ethology established itself by introducing more refined methods to study animal behavior in the wild (e.g. systematic experimentation, note taking, marking individuals). The resulting studies provided answers to questions that remained unresolved by the earlier pioneers. For example, Tinbergen and his co-workers discovered how bee-wolves – a large digger wasp that preys on honey bees –orient themselves and find their nests on the basis of salient visual clues, how they find their prey and so on (Tinbergen, 1974). While ethology thus set new methodological (and also theoretical standards) for research, both Fabre and the Peckhams are named as an important source of inspiration and information by these later ethologists (e.g. Baerends, 1941; Crompton, 1948; Tinbergen, 1974; O'Neill, 2001). The older observations provided a starting point for experimental questions and the controversy between Fabre and the Peckhams – of which the *Sphex* story is a key example – did carry on inside ethology as the fixity versus variability debate (Evans, 1966). How was the *Sphex* story treated in this more rigorous scientific context?

The sophisticated studies performed in the late 1930s, early 1940s by Tinbergen's student Baerends, together with the later Mrs. Baerends, (Tinbergen, 1974; Baerends, 1941) provide a good example. The Baerendses investigated the species *Ammophila campestris* Jur., later renamed as *A. adriaansei*. *A. adriaansei* is fairly small and uses several small caterpillars to feed her developing larva. These caterpillars are provided over several days to avoid the risks of their drying out or getting mouldy (Teschner, 1959). By marking the individual wasps, the Baerendses discovered that this nesting behavior consists of three phases. In a first phase, the wasp digs a burrow, provisions it with a single caterpillar, lays her egg, locks it provisionally and works on another nest. After one or a few days, she revisits the nest without a caterpillar and later brings in one or two, locking the nest and working on another nest. After another day, in a third phase, she returns again without a caterpillar for an inspection, brings in a final collection of three, four or even more caterpillars, bolts the door and never returns. By using artificial plaster nest that allowed the counting and manipulation of the number of caterpillars in the nest, the Baerendses could show that the ‘inspections’ really were *inspections*, the wasp taking stock of the growth of the larva and the number of caterpillars left. The inspection allowed the wasp to adapt its provisioning behavior to these variable factors, an effect lasting through the day and even the day after.

In addition to these findings, the Baerendses investigated many other aspects of the behavior of *A. adriaansei*, such as the visual cues they used to find their nests, but also more basic elements of behavior, such as those involved in the details of nest building and provisioning. In a section called “Drawing in the caterpillar” (Baerends, 1941, pp. 96-105) Baerends reports his findings with the cricket test, here done with caterpillars. Baerends describes the wasp’s behavior as a behavioral chain, each link being the normal precondition for the next: Moving forwards the wasp brings the caterpillar to the side of the burrow leaving it there, the wasp then digs and moves inside the burrow head first, then she moves out backwards, turns around above ground and positions her abdomen above the opening her head facing into the direction she left her caterpillar. Normally she then grabs her prey dragging it in backward. By displacing the caterpillar Baerends could initiate a repeat of up to twenty times (p.97). However, ultimately the wasp abandons the digging and moving inside, releases the caterpillar only for an instant to turn round, then grabs it again and drags it inside moving backwards.

Baerends interprets his findings in terms of a theory of hierarchically organized behavioral chains to explain both the flexibility and rigidity observed. Roughly, the story is that insects, as well as other animals, have a complex hierarchy of internal states (*Stimmungen*). When under the influence of such an internal state, or *Stimmung*, the animal performs actions that belong to this *Stimmung* but not others. In case of the cricket test, the active *Stimmung* of ‘drawing in the caterpillar’ would predispose the insect to repeat itself, but some adaptation is possible by switching to other behaviors that also belong to the same *Stimmung*. The fixity in the cricket test is comparatively strong because ‘drawing in the caterpillar’ is a low-level *Stimmung*, leaving open only a limited number of motor options for changing the behavior. In his general discussion on the variability of action, Baerends notes in his conclusion that both fixity and variability are present in digger wasps, but immediately stresses that often there is only a ‘seeming variability,’ which is not an innate variability but can be explained by the local circumstances under which the behavior is performed, like orientation towards stimuli as in taxis. Baerends seemingly tends to interpret (insect) behavior as fixed, but leaves the issue with the remark that systematic empirical research will be necessary in order to decide (1941, pp. 213ff.).

For the *Sphex* story, two things are important to this report. First, there is the down to earth fact that Baerends found a repetition of twenty times before the wasps managed to escape from their loop. Compared to Fabre and the Peckhams this is an in between case, the repetition being long but not endless. It is not a straightforward support (nor refutation) of the standard message of the *Sphex* story that the behavior is fixed. Second, Baerends study is important for putting the cricket test in its proper perspective. This study became a widely cited classic of ethology because it established how *A. adriaansei* could memorize the state of each of several nests for extended periods on the basis of a single inspection. This discovery, together with many others, made clear that insect behavior was largely unknown territory that was full of surprises and that needed a lot of further research to get a more even handed understanding of it. In the many later studies on increasingly detailed and diverse aspects of insect behavior (e.g. Baerends, 1959; O’Neill, 2001), the cricket test no longer plays a significant role. However, there are still a few later reports on the cricket test. Interestingly, these stress variability rather than fixity of the behavior.

6 Teschner’s study of the fixity–variability question

While the cricket test and its implications play a minor role in Baerends text, a later as well as more focused and in depth study of this issue is provided by Walter Teschner (1959). Teschner starts by observing that the early reports on the behavior of digger wasps are not sufficiently trustworthy and precise and better methods are required. He refers to Fabre and the Peckhams as the origins of the fixity versus variability issue and, while using Baerends’ methods, takes issue with his conclusion that fixity seems to be the more general case. Teschner confirms Baerends’ maximum of a twenty times repeat with *A. adriaansei* before the wasp escapes from its loop (p.454). However he also investigates a different species, *Ammophila sabulosa*, with different results.

Teschner describes how *A. sabulosa* shows two different ways of drawing in the caterpillar. In the first, after leaving the caterpillar at the doorstep, the wasp enters her burrow head first, turns inside and comes out head first, grabs her prey and drags it in. With the second method, the wasp comes out the nest backwards and turns around above ground, like *A. adriaansei*. Doing the cricket test with wasps accustomed to the first method, Teschner comes to a repeat of no more than three or four times (p.456). He also stresses that the repetition of going inside the burrow is not superfluous in this case: The wasp uses this going in to turn around and position herself. To pass the cricket test these wasps have to learn a new behavior, turn at the tunnel entrance. Teschner stresses that in older reports of the cricket test, like Fabre’s, it remains unclear whether the investigated *Sphex* did use the ‘visit’ to turn round inside the nest, which would provide some explanation for its perseverance. The group of *A. sabulosa* that uses the above ground turn can also be made to repeat itself with the cricket test, however also only for a maximum of three to four times before the diving into the burrow drops out and the wasp makes a fast turn (p.457). Another report by Teschner is a single trial with a *Podalinia affinis* wasp, which also turns inside the nest. This wasp persevered in turning inside the nest, leading to a 15 times repeat before it came up very fast, grabbed the caterpillar before Teschner could reposition it ending the experiment (p.459).

Teschner's discussion not only brings in new observations with another species but also additional features that may be relevant for explaining the repetition induced by the cricket test. His noting that the 'superfluous' visit may in various cases be a functional part of a wasp's turning behavior is one. The regular presence of parasites is another possibly relevant fact that could provide a functional explanation for the tendency to keep repeating the inspection. Another interesting feature is the behavior of wasps that make their burrows on sandy slopes where the cricket test tends to occur naturally as caterpillars often slide down the slope. Teschner provides here an 'anti-Sphex story' with his observation of wasp #91. This wasp brings up her caterpillar to the nest opening on a steep slope six times. Each time she tries but does not succeed in grabbing it fast enough when she turns around on the nest opening. The seventh time, she grabs the caterpillar not at its front end but in the middle, drags it up till it is positioned above the nest opening and turns around while braking the caterpillar with her legs, grabs it and draws it in (p.458). Not all wasps are incapable of adapting their behavior and do new things is Teschner's message here.

Like Baerends, Teschner finally concludes that the insects studied show both a lot of fixity as well as variability in their behavior. The main difference is that Teschner tends to stress the variability present in many of the animals studied, while Baerends has a tendency to stress fixity, possibly because this fits his (Lorenzian and Tinbergian) theoretical scheme on innate determinants of behavior better. To conclude, early ethologists were well acquainted with Fabre's cricket test, which was studied more systematically and in more detail than before. While the early positions of Fabre and the Peckhams became cast as the paradigm cases of behavioral fixity and behavioral variability in the ensuing debate it became clear that either position was too strong, or at the very least required more empirical research in order to be established (Baerends, 1941).

7 The *Sphex* story in later behavioral studies

Teschner's study is already fifty years old and since then the number of ethological and other field studies on solitary wasps has expanded enormously (see e.g. O'Neill, 2001) making it increasingly difficult to get an overview of later research that specifically tackles the behavior described in the *Sphex* story. Thus, without any claims of being exhaustive, I want to finish by briefly mentioning a few more recent studies on the variability of behavior in digger wasps.

For example, Steiner (1971), while not reporting on the cricket test itself, tests the wasp *Liris nigra*, in their response to unusual situations and concludes that these wasps can initiate new kinds of behavior under the proper circumstance. He also says, "The fixity of both the activities and of their succession seems, however, to have been overestimated or overemphasized." (p.1401) Ribi and Ribi (1979) refer to Fabre's claims concerning the fixity of the cricket test and report a similar repetition for *Sphex cognatus*, but only "several times before the wasp will grasp her prey and proceed directly into the whole." (p.698)

A wonderfully sophisticated and extensive report on the cricket test derives from a five year study done by Jane Brockman (1985). The cricket test was only one aspect of this study, discussed under the name of "prey-retrieval behavior." First she discusses six natural reasons why the prey of *Sphex ichneumoneus* may be missing when the wasp reappears from the nest. Subsequently she describes the results of the cricket test performed systematically on 31 wasps. For each wasp, she used 15 different places for repositioning the prey, positioned at four different distances (2, 4, 6 and 8 cm) from the entrance, spread in four right-angled directions, the 16th position being the place where the wasp left her prey herself. Brockman placed the prey at each of the 15 non-standard positions in random order, and then finished by placing it in the normal position, from which the wasp always drew it in. Twelve wasps came to the end of the full procedure, repeating the visit fifteen times. Ten wasps drew the prey in from another position, breaking the loop. Of the remainder, five gave up searching for their missing prey while four did not finish for other reasons. In a retest with fourteen wasps, four wasps remained stuck in their loop, while five broke out if it (pp. 639-641). In her discussion, where she also takes into account many other findings concerning the provisioning behavior of the great golden digger, Brockmann says:

> Although the behavior generally follows one scheme, there are many situations that arise and the wasps behave in an adaptive manner towards each … The fixity of repeatedly repositioning and reentering the nest is almost certainly an adaptive response to prey that can easily become lodged in the nest if pulled in backwards. (p.651)

And as a final concluding remark:

> The adaptable provisioning behavior of *Sphex ichneumoneus* would be surprising to anyone who viewed insect behavior as stereotyped and fixed. The versatility of individuals extended to all phases of their behavior, from the habitats in which they hunted, to the types of prey captured, to the behavior used in getting the prey into the brood cell. Where responses show stereotypy, such as in repeated prey retrievals, there is an obvious, adaptive explanation. I suspect that long-term studies of known individuals in other species of insects would similarly reveal the same kind of adaptive behavioral versatility. (p.652)

This message couldn't be further removed from the one conveyed by the *Sphex* story that became part of cognitive science folklore. It is also based on rigorous research and an intimate knowledge of the behavior of these animals and should be heeded more than Fabre's old report.

8 Discussion: The human loop

Having seen its origins, its reception, and later research, it must be concluded that the *Sphex* story as it is known within cognitive science provides a misleadingly one-sided description of wasp behavior. The empirical findings have been equivocal from the very start, giving rise to a long standing debate on the fixedness and variability of insect behavior, a debate that never received a conclusive empirical ending. None of the behavioral scientists in the last hundred years who investigated this particular issue would claim that wasp behavior is completely fixed (as many cognitive scientists currently tend to think; see section 1), nor that it is completely variable of course. Insect behavior in general varies widely, involving many instances of remarkable intelligence, as well as cases that are less so. And even when some individual wasps succumb to the cricket test's repeat, this cannot be taken as evidence for the fixity of insect behavior more generally (Griffin, 1992).

While the *Sphex* story does not teach us a lot about insect behavior, the real interest of the *Sphex* story might lie somewhere else: The tenacity of the story might teach us something important about *human* thought and behavior. The interesting fact is not so much the presumed endless repetition made by the wasp, but the endless repetition of humans retelling the story as a matter of significance despite all the available counterevidence.

The *Sphex* story is not merely an empirical finding like many others but a finding that seems to be particularly intriguing to humans. The story is taken as a special source of insight when it comes to insect behavior, making it "totally opposite to what we feel *we* are all about, particularly when we talk about our own consciousness" as Hofstadter phrased it (see above).

The strong impression left by the *Sphex* story and the endless repetition is not taken in as mere information – compare it for that matter to the specific but rather dry results of Brockmann's experiments on prey retrieval. The cricket test seems to be an eye opening phenomenon that teaches us something deep about the wasps that are described.

Fabre himself thought the original finding remarkable and so did the Peckhams. After them, the cricket test issue remained alive in the behavioral literature till, at least, 1985 gradually becoming less prominent in the context of the general rise of knowledge on insect behavior. Wooldridge in 1963 in turn must have thought the similarities of the repetition to computational routines sufficiently strong to focus on the repetition and to ignore the counterevidence. Later, without the counterevidence or its proper context, the *Sphex* story was evocative enough to spread widely as providing an important and general insight on insect behavior. Even very recently, knowledge of the empirical background of the story does not seem to be sufficient for some researchers to resist using it as an illustration of the presumed rigidity of insect behavior. For example, in their discussion of the difference between noncognitive and cognitive information, Newen and Bartels use the *Sphex* story to illustrate this difference even when they are aware of the Peckhams findings. In a footnote they write:

> In recent work it is questioned whether the description of the behavior of the *Sphex* is adequately evaluated as a rigid behavioral program (Keijzer, 2001). But even if that example cannot play its role here the general idea is clear enough. (Newen & Bartels, 2007, p. 306)

One may wonder here whether cognitive issues should be settled by finding proper examples that fit existing theories or whether theories should be developed that deal adequately and systematically with the findings that nature provides.

Why is the *Sphex* story so persistent? Why does it have such a strong influence on human students of mind and behavior? I will finish by mentioning two different, although not mutually exclusive, hypotheses for the human repetition of the story. First, the story fits in nicely with both dualist and materialist views on the mind, and is used to prop either side. Second, at an intuitive level the story can be said to act as a switching device that at a highly intuitive and salient level enforces a change in the subjective interpretation of this wasp, suddenly turning it from a genuine agent into a mere mechanism.

The first possible explanation derives from the way in which we humans tend to make – or deny – a fundamental difference between mind and matter. The *Sphex* story is relevant in this context because it can be cast as providing a case that is congenial to both sides: What initially seems like a sign of mind in insects is suddenly shown to be a mere mechanism. This demasking is actually usuful to both dualists and materialists. Dualists – like Fabre – use the example to argue that despite the appearance of intelligence, insect intelligence is ultimately only an instinct and not a sign of real mentality: The wasp's behavior is fundamentally different from the nonmaterial human mind, which supports the view that minds are not dispersed widely in nature but are far more exclusive and plausibly restricted to humans. In contrast, later mechanistic philosophers – such as Wooldridge and Dennett – use the same example to claim that as insect intelligence can be shown to be nothing but a complex mechanism, the same would presumably apply to the human case (see also McDougall, 1950). In particular the link between the wasp's behavior and computational routines is used to argue for a deep similarity between biological behavior and machines. Ultimately, this similarity should be extended to humans. So ironically, in both cases, the story can be cast as providing a clear theoretical message – even though precisely opposite to one another – that does not invite a critical attitude towards the findings related in the story.

The second possible explanation that I want to mention derives from empirical research on the automatic subjective interpretation of specific stimuli in either causal terms or in terms of animacy or agency (Mar & Macrae, 2007; Scholl & Tremoulet, 2000). A central point here is that the human capacity to differentiate between agents and non-agents already operates at a very basic, perceptual and intuitive level and is not a purely intellectual judgment. Simple stimuli can be sufficient to evoke the subjective impression of animacy. In an intriguing study Barrett and Johnson (2003) also found that stimuli that usually evoked the impression of animacy ceased to do so when the stimulus array was placed under control by the subject, who could start the display at will. Having control seemed to be a key feature that prevented the perceptual experience of animacy. While there are many differences between these perceptual cases and the *Sphex* story, there are also fascinating similarities. The story also plays out on an intuitive level. It does not relate a neutral finding, but something remarkable that pops up in a salient way. In addition, the story also hinges on an intuitive judgment, here whether this wasp is an agent or not. Finally, the key factor that makes the wasp switch interpretational categories is precisely that it is brought under complete control by the experimenter. These are all good indications that the *Sphex* story is so intriguing (and often repeated) because it plays on very basic and particular, intuitive human tendencies to differentiate between agents and non-agents. If this analysis can be shown to be correct, it would provide a good explanation for the ongoing repetition of the story – as it plays on deep intuitive tendencies – as well as a good reason for its discontinuation.

These hypotheses are not mutually exclusive and together they provide some working ideas for an explanation of the endless repetition of the *Sphex* story among students of behavior and mind. In particular the suggestion that these wasps can be brought under complete control and thus lose their agency is a message that may act as a human superstimulus as known from ethology: Being larger than ordinary stimuli or situations, they are difficult to resist or put down. However, cognitive scientists who are still swayed by the story can use the empirical results provided by ethologists and other behavioral scientists that put the *Sphex* story into its proper perspective. There is no reason for humans to remain stuck in an endless behavioral loop when wasps don't.

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