

# **Abductive Logic of Discovery with Distributed Means**

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## **Abstract**

In this paper I identify various ways that abduction could function as a “logic of discovery”. I delineate two basic interpretations concerning C. S. Peirce’s abduction, that is, inferential and instinctual, and how they fit to N. R. Hanson’s research programme for conceptualizing the area of discovery. I maintain that these perspectives should be broadened to take into account those ideas which have been emphasized in the recent approaches of distributed cognition, given the aim is to understand actual processes of discovery. This broadened approach is in many ways akin to Peirce’s overall philosophy but it means that basic conceptions of abduction have to be embedded, to be a part of socially, materially, culturally, and temporally distributed cognition. I analyze briefly consequences of distributed cognition for conceptualizing abductive processes of discovery.

Keywords: abduction, distributed cognition, discovery, Hanson, Peirce

## **Introduction**

In the 1950s and 1960s, N. R. Hanson (1958, 1961) suggested that Charles S. Peirce’s abduction may serve as a basis for a “logic of discovery”. Hanson’s aim was not any formalistic system of logic, yet he maintained that Peirce’s basic formulation of

abduction provides a conceptual apparatus for understanding those processes through which new ideas and theories are discovered, and new explanations of phenomena are searched for (Hanson 1958, 2-3). Most philosophers at that time maintained that such conceptualization is *not* possible. According to them processes of discovery can not be analyzed conceptually and with philosophical means, only those ways by which the idea is justified. In many ways this is still the prevalent conception.

Peirce's own writings concerning abduction have left room for various interpretations, which bear upon its possible use in accounting for discovery. Abduction as a third main mode of reasoning seems to imply that Peirce was aiming at finding a logic of discovery. On the other hand, in his later writings, Peirce emphasizes that abduction is very close, or even the same as a guessing *instinct* for finding fertile ideas. This seems to imply that there is no *logic* of discovery, but rather discovery is about such things as instinct, intuition, and guessing. Peirce himself, in his later writings, did not make any difference between these two ways of interpreting abduction but subsequent interpretations have often emphasized either inferential or instinctual aspects of abduction.

It can, however, be argued that these two basic ways of interpreting abduction are not enough if the aim, like Hanson's, is to understand and conceptualize processes of discovery with abduction. They easily depict inquiry in too rationalistic, mentalistic and individualistic terms, as if discovery were something which human beings do just by making inferences within their own mind. In any case, modern ideas concerning *distributed cognition* have forcefully challenged this kind of a picture about human rationality (Salomon 1993; Hutchins 1995). But what happens to abduction and to the idea of logic of discovery if distributed cognition is taken seriously?

In this paper I first briefly delineate Peirce's own development concerning abduction. Then I present what I think was the main idea behind the Hansonian "research programme" on a "logic of discovery". After that, I analyze how the ideas of distributed cognition have been and could be taken into account within abduction. Distributed cognition gives new means for understanding processes of discovery with a broader and

more realistic framework than before. In many respects Peirce's ideas fit well with modern ideas about distributed cognition, but these kinds of ideas are *not* very prominent in his specific theory concerning *abduction*. I maintain that distributed cognition is one central direction where abductivist methodology should be developed if the aim is to develop conceptual means for understanding processes where new ideas and hypotheses are generated and developed.

### **Basic interpretations of Peirce's abduction**

Peirce's writings concerning abduction are usually separated into two main periods although the change was not an abrupt one (Burks 1946; Fann 1970; Anderson 1987). The first period can be called a "*sylogistic*" (or "evidential") interpretation of abduction (from 1860s to about 1890s) when Peirce interpreted abduction through various forms of syllogistic reasoning, and as a weak form of an evidencing process. Abduction is then seen as an inversion of Barbara syllogism so that the minor premise is abduced from the conclusion and the major premise. In his later writings (about 1890s onwards) Peirce did not abandon this interpretation as such but he emphasized that abduction is an essential element of the first phase of inquiry where ideas are originated for subsequent testing. This later, "*methodological*" approach had a broader view on inquiry than the earlier approach.

The change from syllogistic interpretation to methodological interpretation in itself was not a very large one because in his later writings Peirce still maintained that abduction is a form of reasoning with a similar syllogistic basic structure that he had presented earlier. A clearer change was that in his later writings Peirce maintained that abduction has its basis in an "*instinct*" for finding or guessing fertile hypotheses (CP 7.219, 1901<sup>1</sup>). Peirce presented various rationales for this instinct in his writings during the years (Shanahan 1986; Paavola 2005), but the basic idea was that the success of human beings of finding good hypotheses cannot be explained except by assuming that there is some kind of a tendency of human beings for finding promising ideas. Peirce also proposed that abduction is near to perceptual judgments, so it is akin to perceptual insights (CP 5.181,

1903; Hanson 1958). This has led to difficulties of interpreting how abduction can be both a form of an inference and a sort of an insight (or an instinct) at the same time (Frankfurt 1958, 594; Fann 1970, 35; Anderson 1987, 32,35).

Subsequent interpretations of Peirce's abduction has often emphasized abduction either as an inference or as some sort of an instinct (or an insight) by either treating abduction as a "pure" form of inference without giving any special role for an instinct, or, by interpreting abduction as a sort of an "intuition" for noticing clues and signs and finding solutions for difficult puzzles (see e.g., Eco & Sebeok 1983). Often these interpretations are mixed together without making any clear analysis how they are related. For example, when Hanson developed his notions concerning abduction as a "logic of discovery", he appealed to the inferential structure of abduction, and the way how scientists reason from surprising phenomena to new explanations (Hanson 1961). He did not appeal to any instinct here. On the other hand, Hanson connected abduction to "Gestalt" switches, and to "seeing" new kinds of patterns in phenomena (Hanson 1958). Peirce already had maintained that abduction

"shades into perceptual judgment without any sharp line of demarcation between them; or, in other words, our first premisses, the perceptual judgments, are to be regarded as an extreme case of abductive inferences, from which they differ in being absolutely beyond criticism" (CP 5.181, 1903).

But this does not in itself solve the dilemma when it comes to the logic of discovery. Is abduction supposed to be a form of inference from data to hypotheses, or is it more like a sudden flash of insight based on a mysterious capacity of human beings of interpreting things? If it is both, how are we supposed to connect these two?

Peirce himself never called abduction as a 'logic of discovery'. Still, this kind of an interpretation is easy to make for many formulations which Peirce proposed concerning abduction, especially in his later writings. In his early writings, abduction concerned more justification, and in the later writings discovery (Thagard 1981) although the change is not an abrupt one. In his later period, Peirce maintained that abduction "furnishes all our ideas concerning real things, beyond what are given in perception" (CP

8.209, c. 1905). Peirce also wrote that “[a]ll the ideas of science come to it by the way of Abduction. Abduction consists in studying facts and devising a theory to explain them.” (CP 5.145, 1903). Peirce often seemed to emphasize that the instinctual tendency to guess right is the key for explaining how new ideas are generated<sup>2</sup> although there was no sharp contrast with “reasoned” and “instinctive” considerations (CP 7.220, 1901).

My own interpretation is that abductive inference and abductive “instinct” should be separated more clearly than Peirce did in his later writings (Paavola 2005), but both of them should be developed further if abduction is to be understood as a way of conceptualizing actual processes of discovery. But besides these, a methodological treatment of abduction can be expanded to those areas which are emphasized within *distributed cognition*. Although Peirce’s and Hanson’s basic models of abduction were different from distributed cognition, their approaches provide means for broadening abductive logic of discovery.

### **How to conceptualize the area of discovery?**

For Peirce, one basic motivation for abduction was his contention that there has to be a way by which people have managed so successfully to find fertile and true theories for various phenomena. According to Peirce, this could not have been a random process, because there would not have been enough time for that in human history (CP 7.220, 1901; also CP 5.172, 1903; CP 5.591, 1903). Both an inferential and an instinctual interpretation of abduction can be developed so that they clarify how abduction makes this success understandable (Paavola & Hakkarainen 2005). But they are not enough in themselves.

Hanson maintained that there are reasons for suggesting hypotheses and not just for accepting and testing them, against the prevalent thought style in philosophy of science in his time (Hanson 1961). What he meant with “logic of discovery” was a conceptual inquiry concerning the area of discovery, not a manual or an algorithm for making discoveries (ibid., 21). Hanson wanted to conceptualize “the dawning of an explanation”

and the way that scientists produce, or “press on” for new explanatory hypotheses on the basis of data and phenomena, and he took Peirce’s abduction as a central conceptual means for doing this (Hanson 1958, 85-90). Later, when discovery was recovered as an important topic for philosophy of science, Hanson was praised as an important forerunner for discovery, but his formulations of abduction were treated as insufficient for explaining the area of discovery. The basic criticism against Hanson was that his formulations of abduction failed to provide a basis for a logic of discovery, and gave a too narrow picture of the area of discovery (see Nickles 1980, 22-25). Similar doubts still linger on discussions around abduction and a logic of discovery. There are doubts if it is even in principle possible to develop a separate “logic of discovery”, and specific formulations of abductive inference have been criticized as inadequate (Kapitan 1990; 1992).

I maintain that a Hansonian research programme concerning logic of discovery can be continued although his own formulations of abduction are not entirely adequate. Hanson was not so much searching for a separate logic of discovery, but maintaining that the way that scientists press on for new explanations and hypotheses can be conceptualized. Discovery is not just about logic or reasoning, but still there *are* also reasons for suggesting hypotheses, and various forms of abduction are one way of conceptualizing these processes.

For me, the gist of abduction is those things which constrain and guide the search for new, tentative ideas and hypotheses. Abduction is a weak form of inference where clue-like signs, tentative restrictions, and search for overarching patterns are used as aids when new ideas are searched for. Although it is a weak form of inference, it is better than pure chance. There is no rule-book for making discoveries, but still, abductive processes help us to understand how new ideas are searched for.

According to prevalent creativity myths in our culture, new ideas burst out from the minds of lone geniuses fighting against social conventions and traditional, stagnant thought styles of their time (Sawyer 2006, 259). Or they are the result of reasoning

powers of these exceptional people. These myths are not totally wrong. New ideas often require that fossilized ways of interpreting things be seen in a new light, and often individuals start these processes by pushing forward new lines of research and new, insightful ideas. But this is just one part of the story. Individuals work in particular historical and cultural contexts and in an interaction with other people and their environment while developing new ideas. Here the ideas of distributed cognition become important.

### **Abduction and distributed cognition**

Distributed cognition is an approach within cognitive sciences which emphasizes that human cognition is not confined to individuals and within individuals' minds but is distributed in essential ways to surrounding physical, social, and cultural environments and to long-term temporal processes. It emphasizes social and situational aspects of cognition rather than mental constructions within human mind. The term itself has become popular since the late 1980s (see Oatley 1991), but the idea has many predecessors, such as L. S. Vygotsky's idea of the mediated nature of human cognition (Vygotsky 1978).

Basic interpretations of abduction seem to be in contrast to distributed cognition, or at least they do not promote that kind of thinking. If abduction is interpreted inferentially (or syllogistically), it means that the process is something a-personal (a relationship between premises and a conclusion), or done by an individual reasoner within his or her mind. If abduction is interpreted instinctually or close to perception, it seems to be a process where social interaction, or cultural and material artefacts do not have a prominent role. Much, of course, depends on how Peirce's notion of an instinct (or perception) is interpreted. There are elements also within inferential and instinctual interpretations of abduction which have connections to the ideas of distributed cognition. Abduction starts from an interaction between a human inquirer and its environment (see Neshet 2001). A starting point for abduction is perceptual judgments and surprising phenomena which instigate the search for new ideas (CP 5.182-194, 1903). Abduction is

a part of an interrogative process (CP 6.525, 1903; CP 6.469, 1908; Sintonen 2004; Hookway 2005; Paavola, Hakkarainen & Sintonen 2006). Peirce also held that abduction is closely related to, or even the same as, the *maxim of pragmatism* (or “pragmatic maxim”), that is, explanatory hypotheses produced should be capable of experimental verification (CP 5.195-198, 1903).

Peirce’s philosophy in general has affinities with the ideas of distributed cognition. According to Peirce’s semiotic perspective and in opposition to mentalistic tradition, even individual minds are very fundamentally social, developing in intersubjective sign processes (Colapietro 1989). Peirce’s anti-Cartesianism meant that signs mediate human cognition in a fundamental sense (CP 5.213-357, 1868-1869). For Peirce, signs include all kinds of sign processes, not just, for example, symbolic signs but also indexical signs, some of which have material form, where the real connection of signs with dynamic objects is central (see Liszka 1996). Peter Skagestad (1993; see also Magnani 2006) has also shown how Peirce represented an “augmentationist” approach to mind and knowledge, according to which human thinking should not be seen so much as a process that happens inside the human head but as something where human mind uses various sorts of external artefacts, tools, and methodologies. For Peirce, the augmenting things were especially signs and sign processes.

Peirce did not, however, emphasize social, cultural, or material elements in relation to *abduction* in particular. Karl-Otto Apel has remarked that although Peirce emphasized the role of community especially in his early works concerning human cognition, he seemed to interpret abduction as if it were a “logically mediated exchange of information between each individual person and nature” (Apel 1981, 170-171). What is missing is the role of social interaction and community of interpretation as a basis for new ideas. Peirce emphasized the guessing instinct, or “*il lume naturale*” (a sort of a natural bent) in his later writings (CP 1.80-81, c. 1896), and neglected “*il lume culturale*” (Bonfantini & Proni 1983, 134; Bonfantini 1988, 1253-1254). Peirce did not emphasize material objects or external artefacts in setting out a basis for abduction (also “*il lume materiale*” was then



neglected). Similarly N. R. Hanson mostly neglected the role of material and social elements in his analysis of discovery.

There are some recent analyses which interpret abduction within distributed cognition. Keith Oatley has made this connection explicitly (Oatley 1996). When scientists are developing new ideas they are “standing on the shoulders of giants”, that is, they are using cultural knowledge produced by other researches (ibid., 137). Inquiry is basically a social process: “[w]hile one person puts forward a hypothesis, someone else sees what is wrong with it, yet others find syntheses and provide wider contexts” (Oatley 1991, 102). Even when the inquirer is apparently doing his research individually, he or she is using and developing concepts, theories and observations developed by others, and trying to communicate, develop and defend them for other people. So the focus should not be just on an individual having insights or making inferences but also on the interaction with social and material environment which provide a basis for these insights and inferences.

Lorenzo Magnani has emphatically developed ideas belonging to distributed cognition especially with the notion of *manipulative abduction* (Magnani 2001, 53-69; 2004). Manipulative abduction “happens when we are thinking *through* doing and not only, in a pragmatic sense about doing” (Magnani 2004, 229). It uses “epistemic mediators” or external forms of representations (like diagrams and models) when people are collaboratively solving some problems or performing tasks. It has its basis in both concrete manipulations of external objects and on cognitive division of labour among people. Models of cognition should take into account the interplay between internal and external representations (Magnani 2006). Human beings are able to use various kinds of representations, which are especially important when something new is created.

How do the ideas of distributed cognition change the interpretation of abductivist methodology? Roy Pea (1993, 65-67) has maintained that prevalent “myths” of standard problem-solving models present inquiry in linear stages and as constructions done by individuals with mental means; whereas according to distributed cognition problem solving is more about cyclic, iterative systems done by social communities with external

representations and artefacts and in relation to features of the environment. If abduction is presented solely as a first stage of inquiry where a hypothesis is derived on the basis of premises, or on the basis of an instinct (or an insight), it leaves this larger framework very much out of sight. From this point of view the problem of inferential and instinctual interpretations is not so much that they are wrong but they focus too narrowly on some aspects of the overall process of discovery.

Distributed cognition gives extra means for understanding those elements which guide and constrain abductive search for new and plausible ideas. It emphasizes, for example, the points below. It is not being claimed that these are, necessarily, absent in Peirce, especially as regards 'seed' form; they are laid out to provide a basis for detailed consideration of possible elaboration and extension of Peirce's framework to include distributed cognition.

1) *The search for abductive ideas has its basis in long-term, iterative and reflective processes.* Basic models of abduction give an impression that new hypotheses turn up by starting from a surprising phenomenon and finding a hypothesis candidate to explain that phenomenon (if that hypothesis turns out not to be successful, a new candidate must be produced, and so the process goes on). An instinctual alternative is to say that new ideas turn out as sudden moments of insight when the inquirer realizes a new pattern which explains previously puzzling data (Hanson 1958). Both of these approaches leave out phases preceding these. Ideas are often worked out for a long period of time. They develop and change during this process, but new ideas have their bases in the phases that help to see the constraints and clues that provide guidance to the discovery process. As an example, Hanson (1958, 72, 89) has mentioned that it took, in all, 34 years for Galileo Galilei to develop his constant acceleration hypothesis, and abductive methodology should clarify this whole process, not just the end result or the crucial insight. The same applies to all major discoveries<sup>3</sup>. The elements and material for new ideas develop during a long process and in relation to hypotheses and ideas tried out before. The abductive process is temporally distributed.

- 2) *In empirical sciences clues and elements instigating and constraining new ideas are not just propositional but come from an interaction between the inquirer(s) and the object of research.*<sup>4</sup> In a paper called “Guessing” Peirce maintained that human beings are able to notice “intimations of truth” (CP 7.46, 1907) as an aid when guessing new explanations for intricate problems (Peirce 1929)<sup>5</sup>. Peirce did not speculate much what is the source of these “intimations” or clues for new ideas. From the point of view of distributed cognition, one clear source is the human encounter with the objects and events of the material world. The abductive search is then materially distributed.
- 3) *Not just propositional means but also social practices guide human inquiry.* Research practices and paradigmatic ways of doing research in a particular field in a particular historical situation on the basis of its historical background very much determine how things are understood and developed. It may be argued that the discovery of new ideas and theories means that these old habits of action are rejected or radically changed. Still, not all practices and habits can be changed at once, but they are partly guiding the process of inquiry. Thus it can be said that cognition is socio-practically distributed.
- 4) *Ideas are not developed just by individuals, but human beings build on each other's ideas in a fundamental sense.* Human beings are social and communicative animals. Other people give elements and clues for new ideas (both consciously and unconsciously) when commenting, discussing, or writing on each other's ideas. In this sense, a basic unit of an analysis for understanding processes of discovery should rather be scientists as members of research communities, or networks of inquirers than an individual scientist doing research. Inquiry is socially distributed.
- 5) *Inquirers use culturally shared knowledge in developing new ideas.* The time-scale of human activity reaches beyond individuals. Culturally created and shared knowledge, artefacts, methods, and tools provide means for human inquiry. Inquirers do not need to start from scratch because these cultural resources guide the inquiry. Very often to develop something new means that culturally stabilized ways of doing or interpreting things are changed or neglected, but not all can be changed or neglected at once. Inquiry is also culturally distributed.

6) *Not just inferences within the inquirer's "head" are important, but also the meaning of various external tools and artefacts.* External artefacts, tools and representations are central when ideas are socially and culturally developed and dispersed. External, shared objects and artefacts are important even when inquirers have competing theories about their meaning (Magnani 2006). People externalize their ideas to external representations because otherwise they would not be available for others to use. Inquirers use, modify and create these external artefacts while developing new ideas. Ideas are distributed in external artefacts.

Distributed cognition challenges previous models concerning inquiry, knowledge and thought. It gives new means for conceptualizing processes of discovery. Instead of concentrating on processes within one's mind, or on an interaction between the inquirer and nature, or between people it means that new kinds of conceptualizations concerning human activity must be developed. It can be maintained that its basic form is a "three-player" situation, that is, an interaction with the inquirer, a community of fellow interpreters, and "nature" (i.e., the object of inquiry) (see Pera 1994; cf. Davidson 2001).<sup>6</sup>

## **Conclusion**

The concept of distributed cognition gives new means for conceptualizing abductive processes of discovery. Peirce's writings on abduction have led to emphasize inferential or "instinctual" interpretations of abduction, but Peirce's texts are amenable to the ideas emphasized with distributed cognition. Peirce's overall philosophy is *not* hostile to the ideas of distributed cognition, but much research remains to be done on what it means that abductive processes are socially, culturally, materially and temporally distributed. N. R. Hanson brought forward emphatically the idea of logic of discovery, that is, the need to conceptualize the area of discovery. I maintain that Hanson's research programme can be expanded to areas of distributed cognition. I think that in order to understand better the area of discovery, the aim is not to *substitute* prevalent interpretations of abduction as such, but to supplement and extend these models through a broader perspective on

abduction. Understanding processes of discovery requires that various layers of abduction be taken into account.

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<sup>1</sup> ‘CP v.ppp, xxxx’ refers to Peirce’s Collected Papers (see Peirce 1931-1958) in a customary way by indicating after CP a volume number (v), a paragraph number (ppp) and the year when the manuscript was written (xxxx).

<sup>2</sup> “... every plank of its [science’s] advance is first laid by Retroduction [i.e. abduction] alone, that is to say, by the spontaneous conjectures of instinctive reason”. (CP 6.475, 1908)

<sup>3</sup> And probably this applies also to minor, everyday discoveries. If I, for example, invent an original and a good idea of what to buy for a friend as a birthday present, it has been formed not just by a sudden insight or one line of an inference, but by various previous constraints and clues concerning, my knowledge, e.g., those things that are usually bought as presents, what kind of things my friend likes, and so on. In order to understand properly how the new idea comes up, these preparatory processes should be taken into account.

<sup>4</sup> Cf. also a “multimodal” approach on abduction, that is, Thagard has emphasized that for human problem solvers clues and hypotheses within abduction can also be other than propositional or verbal representations, like sights, sounds, smells, touches, emotional feelings, visual patterns, and kinesthetic experiences (Thagard, forthcoming). Thagard connects this to neural mechanism and to a neurocomputational theory of abductive inference, but it can be extended to cover also external representations (Magnani 2006).

<sup>5</sup> Some parts of this paper are published in Peirce CP 7.36-48, 1907. The whole paper is published in *Hound & Horn* magazine from 1929, pp. 267-282, and described at length in Sebeok & Umiker-Sebeok 1983.

<sup>6</sup> On the basis of this, we have been developing a “trialogical” model of inquiry conceptualizing an approach where inquirers are developing collaboratively and with cultural means in long-term processes some shared objects of activity (Paavola, Hakkarainen & Sintonen 2006). The term “trialogue” (cf. a bit different but related use of the term by Wiley 1994) is a contrast to “monological” models of human cognition (concentrating on processes within one’s mind) and to “dialogical” models (concentrating on an interaction between people or between a human being and nature).

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