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Original Contributions - Originalbeiträge

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Why *Experimentum Crucis* is Possible in Psychology of Perception

Different scientific disciplines have different methodological approaches to the empirical world. For example, abstract disciplines, such as modern physics, in which empirical entities are often little more than mathematical constructions, have a net indirect relationship between theory and *empiria*. Experiments, i.e., the *praxis* of conjunction of these two last terms, usually show only data obtained from indirect observations, where natural perception is mediated by a long series of instrumental stages. One of the main meta-methodological problems for this scientific domain is to ensure the effective empirical value of the hypothetical concepts subject to an experimental control. In contrast, perceptual studies, particularly from an experimental phenomenological point of view, have the structures of the perceptual immediate experience as objects of study. In this case, the experimental observation does not require any instrumentation but only the immediate experience of the observer. In this experimental domain, the main problem is to ensure the effective theoretical value of perceptual laws, which are "empiric laden".

Another remarkable meta-methodological difference between physics and Experimental Phenomenology (see Kanizsa, 1979; Thinès, Costall, & Butterworth 1981; Bozzi, 1989, 1999; Masin, 2002; Sinico, 2003; Verstegen, 2005; Zavagno, Antonelli, & Actis Grosso, 2008; Toccafondi, 2012; Calì, 2017) is the isolability, i.e., the possibility of testing only one theory in isolation toward other theories. However, in abstract disciplines, such as physics, every theory or hypothesis is necessarily linked to some assumptions. In Experimental Phenomenology, one single law is isolated, without any theoretical assumption, because it is the state of a perceptual experience under observation. This difference has relevant consequences, particularly on the holistic thesis, better known as the "Duhem-Quine thesis", according to which the test of a scientific hypothesis in isolation is impossible.

The goal of the present paper is to show how, within Experimental Phenomenology, it is possible to obtain the falsification of one of two rival perceptual theories through *experimenta crucis.* There is a long and rich debate in philosophy of science about *experimentum crucis,* which has concerned important philosophers such as Francis Bacon, Franz Brentano, the physicist Pierre Duhem, Karl Popper, and so on. The first introduced this methodological instrument in the 17th century, as we can read in the *Novum organum*. According to Bacon, when a scientist has liberated the mind from the "Idola", he/she can discover the hidden causes of natural phenomena by a specific step of his experimental procedure that uses induced reasoning.

1. *Experimentum Crucis* in Physics

This step is well represented by the *instantiae crucis* (crucial instances), "so called by a term taken from the crosses erected at the intersection of roads, which show and announce a bifurcation" (Bacone, 1620). Therefore, the *instantiae crucis* are critical decisions, such as those taken when approaching bifurcations of the road: they are a definitive choice among two diverging theoretical options. On the basis of this earlier definition, which was discussed later also by several philosophers and scientists, such as Descartes and Newton, it is possible to express this term formally: given a first theory (or hypothesis) T1, which is followed by a controlled consequence c1, and given a second theory (or hypothesis) T2, which is followed by a controlled consequence c2, if $c1 = \neg c2$, then T1 is true and T2 is false; or (exclusive disjunction) T2 is true and T1 is false. On this basis, the *experimentum crucis* establishes whether c1 or c2 is given, and, as a consequence, whether T1 or T2 is true.

In the more recent history of philosophy of science, the *experimentum crucis* has been discussed widely (see Gillies, 1993). In particular, researchers debated the closely related problem of induction. One of the more important theoretical examinations comes from Pierre Duhem (1906); but now I refrain from discussing this contribution until after presenting the work of Karl Popper, chronologically subsequent, because the critiques to Popper's Falsificationism used Duhem's thesis.

The Austrian philosopher started from a critique against induction (Popper, 1934–1959). Generally, the problem of induction concerns the possibility to use inductive inference, from singular assertions, which are reports of results of observations or experiments, to universal assertions, which are hypotheses or theories. In any case, also if the singular assertions are numerous, according to Popper, "no number of sightings of white swans can prove the theory that *all* swans are white (1959, p. 4)"". An inductive inference, according to Popper, is necessarily justified on the basis of a logical principle of induction; but this principle is also a universal assertion. As such, to have a justification, it further requires inductive inferences. These inferences cannot assume a principle of induction, and then it goes into a *regressum in infinitum*.

After treating the problem of induction, Popper criticized also the Verificationism, which was, in the 1930s, an important theoretical principle for the Vienna Circle. By this principle, in a very schematic view, a sentence only has meaning if it can be verified. According to Popper, accepting this principle, important scientific laws, which require a large number of verifications, would be excluded. Instead, he proposed the principle of Falsificationism. While an infinite number of observations or experiments are necessary to verify a theory, to demonstrate the falsification of a theory only one counterexample is sufficient.

Then, Falsificationism can be reduced to a logical inference of classical logic, well known as *modus tollendo tollens*, for which

$$((T\text{-}> c) \wedge \neg c)\text{-}> \neg T \qquad (1)$$

That is, from the universal assertion T, it is possible to make a logical deduction of the consequence c, in the term of a singular assertion; but where the consequence c is not given, the consequence T is also not given. In other words, from a scientific theory it is possible to deduce singular assertions that are subject to the empirical test. Every theory is scientific only if these assertions (so-called potential falsifiers) are able to refute their own theory. Then, if one of these singular assertions would be false, the theory will be falsified; if the same singular assertion is true, the theory will be *at that moment* true.

Proceeding in this way, with sucessive falsifications, the weaker theories can be eliminated. Then the criterion of falsifiability resolves both the problem of demarcation between science and pseudo-science: an assertion can be scientific only if it is falsifiable, and selection of theories would be far from beeing true. The theories that are not yet falsificates, without a condemnation by the empirical test, move closer to being true. These theories are content to be *verisimilar*. According to Popper:

> In the most cases we have, before falsifying a hypothesis, another one up our sleeves; for the falsifying experiment is usually a crucial experiment designed to decide between the two. That is to say, it is suggested by the fact that the two hypotheses differ in some respect; and it makes use of this difference to refute (at least) one of them (1959, p. 87).

The *experimentum crucis* is a fundamental methodological instrument within Falsificationism. The Austrian philosopher defines this instrument in *The Logic of Scientific Discovery*:

> It should be noted that I mean by a crucial experiment one that is designed to refute a theory (if possible) and more especially one which is designed to bring about a decision between two competing theories by refuting (at least) one of them – without, of course, proving the other (1959, p. 277).

Thus, Popper accepts the *experimentum crucis* while he critiques what Bacon believed to obtain by this method. It is possible to compare two theories if they are at a point of intersection; but, according to him:

> (…) while Bacon believed that a *crucial experiment* may establish or verify a theory, we shall have to say that it can at most refute or falsify a theory (1963, p. 150).

Between two rival theories, by the *experimentum crucis,* one will be falsified while the winning theory can only be corroborated until it is falsified.

Instead, according to the great physicist Pierre Duhem, to believe that it is possible to establish the truth of a theory by a dichotomy is a wrong analogy with the demonstrative procedures of Euclidean geometry (Duhem 1906). Through these procedures, a sentence can be demonstrated valid when a contrary sentence is demonstrated false by a *reductio ad absurdum*. That is the same procedure that is used by Bacon to promote the *experimentum crucis.*

> Do you wish to obtain from a group of phenomena a theoretically certain and indisputable explanation? Enumerate all the hypotheses that can be made to account for this group of phenomena; then, by experimental contradiction, eliminate all except one; the latter will no longer be a hypothesis, but will become a certainty. Suppose, for instance, we are confronted with only two hypotheses. Seek experimental conditions such that one of the hypotheses forecast the production of one phenomenon and the other the production of quite a different effect; bring these conditions into existence and observe what happens; depending on whether you observe the first or the second of the predicted phenomena, you will condemn the second or the first hypothesis; the hypothesis not condemned will be henceforth indisputable; debate will be cut off, and a new truth will be acquired by science (p. 188).

Duhem maintains that this schema is logically unacceptable in physics because two opposed theories are not necessarily a complete disjunction. A third theory is still possible and the rival theories are not finite.

On the same pages of *The Aim and Structure of Physical Theory* (1906), there is also a decisive critique against Falsificationism.

> "The prediction of the phenomenon, whose nonproduction is to cut off debate, does not derive from the proposition challenged if taken by itself, but from the proposition at issue joined to that whole group of theories; if the predicted phenomenon is not produced, the only thing the experiment teaches us is that among the propositions used to predict the phenomenon and to establish whether it would be produced, there is at least one error; but where this error lies is just what it does not tell us" (1954, p. 185).

In other words, the *experimentum crucis* cannot demonstrate that a theory is both true and false, because every theory is always connected to a set of other theories, assumptions, and reliances on the experimental setting. As a consequence, the outcome of the *experimentum crucis* could be the result of any one of these connections. This methodological holistic thesis (which is different from the semantic holistic thesis by Quine also, even though they are often associated) can be expressed in logical terms as follows:

$$< T \wedge T1 \wedge T2 \wedge \ldots \wedge Tn > \qquad (2)$$

where T1, T2, …, Tn comprise a system of underlying premises connected to the theory T. As a consequence, the expression in Equation (1) becomes

$$((< T \wedge T1 \wedge T2 \wedge \ldots \wedge Tn > \text{->} c) \wedge \neg c) \text{->} \neg < T \wedge T1 \wedge T2 \wedge \ldots \wedge Tn > \qquad (3)$$

In accordance with the law of De Morgan,

$$((< T \wedge T1 \wedge T2 \wedge \ldots \wedge Tn > \text{->} c) \wedge \neg c) \text{->} \neg T \vee \neg T1 \vee \neg T2 \vee \ldots \vee \neg Tn \qquad (4)$$

In conclusion, by *experimentum crucis* it is impossible to know which the false T term is. In his *Postscript to the Logic of Scientific Discovery*, Popper has replied to this argument.

> More serious is an objection closely connected with the problem of *context*, and the fact that my criterion of demarcation applies to *systems of theories* rather than to statements out of context. This objection may be put as follows. No single hypothesis, it may be said, is falsifiable, because every refutation of a conclusion may hit any single premise of the set of all premises used in deriving the refuted conclusion. The attribution of the falsity to some particular hypothesis that belongs to this set of premises is therefore risky, especially if we consider the great number of assumptions which enter into every experiment (1983, p. 187).

However, if theory T is falsifiable only in conjunction with other theories ($T \wedge T1 \wedge T2$), then the conjunction $T \wedge T1 \wedge T2$ would be scientific but the theory T would be metaphysical. As a consequence, important laws of nature, such as Newton's first law, would be considered not scientific. In fact, to be falsified, it requires the assumption of Newton's second and the third laws to be true. This is in open contradiction to Popper's own criticism of verificationism. He criticized that verificationism excludes important laws of nature (Gillies, 1993). Moreover, it is impossible to demonstrate the scientificity of a theory T on the basis that T is included within one or more systems of falsifiable theories, such as $<T1 \wedge T2 \wedge \ldots \wedge Tn>$. According to the argument of

Ayer (1936–46), Newton's first law would be considered scientific but, at the same time, would be considered scientific whatever metaphysical statement (Gillies, 1993).

Thus, Popper was obliged to admit that (provisionally) true background knowledge is logically necessary to falsify a theory.

> Against the view here developed one might be tempted to object (following Duhem) that in every test it is not only the theory under investigation which is involved, but also the whole system of our theories and assumptions – in fact, more or less the whole of our knowledge – so that we can never be certain which of all these assumptions is refuted. But this criticism overlooks the fact that if we take each of the two theories (between which the crucial experiment is to decide) *together* with all this background knowledge, as indeed we must, then we decide between two systems which differ *only* over the two theories which are at stake. It further overlooks the fact that we do not assert the refutation of the theory as such, but of the theory *together* with that background knowledge; parts of which, if other crucial experiments can be designed, may indeed one day be rejected as responsible for the failure (1969, pp. 150–151).

Nevertheless, to conclude, if the theory is to be taken together with the background knowledge, it is still impossible to establish which particular knowledge is responsible for experimental falsification and which particular knowledge is true.

Returning to Duhem, it is now important to underline that his thesis has clear and distinct boundaries. As he writes:

> When many philosophers talk about experimental sciences, they think only of sciences still close to their origins, e.g., physiology or certain branches of chemistry where the experimenter reasons directly on the facts by a method which is only common sense brought to greater attentiveness but where mathematical theory has not yet introduced its symbolic representations. In such sciences, the comparison between the deductions of a theory and the facts of experiment is subject to very simple rules (1906–1969, p. 180).

That is to say, in scientific disciplines that have a low level of theoricity, compared to physics, the logical connection between observation and theory is less problematic. In fact, in these disciplines, the mathematical reduction and the symbolic representation cannot be always necessary. The main examples of these scientific disciplines with low level of theoricity are perceptual studies, particularly from an experimental phenomenological point of view.

2. *Experimentum Crucis* in Perception

Experimental Phenomenology of perception is one of the most scientific disciplines with low theoricity. In this discipline, the *experimentum crucis* has been adopted since the perceptual studies of Franz Brentano. To demonstrate the truth of his hypotheses, in his research on optical illusion of Müller-Lyer, he used concrete exemplification (Cattaruzza, 1999). Brentano states as follows:

> I wanted to show, through a visual example, what an ordinary psychological procedure can do and the way in which the experimentum crucis of the human sciences, no less than in natural sciences, decides with certainty between two rival hypotheses (1897, p. 114).

The experimental methodology of Brentano was degraded by Boring (1950) to the empirical method:

> Thus Brentano, in arguing about the optical illusion, was quite ready to draw newforms of old illusions and so pictorially to submit his case on the printed page to the experience of the reader: this is the empirical method in concrete form, the *experimentum crucis*. But Brentano never undertook to measure the amounts of illusions under different conditions by the psychophysical methods: this course would have been the experimental method and would have yielded more precise information about the points in question. The *experimentum crucis* belongs in an argument and is thus apt to be part of the empirical method. Systematic experimentation yields precise description and is the *sine qua non* of the experimental method" (1950, p. 360).

Aside from the fact that Brentano takes into account different conditions under which the illusion can be studied (Calì, 2017), Boring confused the form of *experimentum crucis* with the method of demonstration (see also Boring, 1927). Brentano used the latter by the schema of the former to prove the truth between two rival hypotheses. If a perceptual demonstration can assume the logical form of *experimentum crucis,* it is a mistake to believe that the *experimentum crucis* is always a demonstration or a simple empirical method. Through out history, in experimental science, there has always been mesurable or statistical experimentation using *experimentum crucis*. A good example is the Michelson and Morley's *experimentum crucis*, which, by measuring the speed of light, proved Einstein's special theory of relativity.

Differently, a reasonable comparison regards the classic experimental method, based on measurable or statistical values, against the experimental demonstration, based on the variation of the independent variable, to observe the effect on the dependent variable without measures (Sinico, 2008).

The methodology of Brentano is easily a consequence of the specific empirical object of study. In fact, he was oriented toward bringing out universal laws, immanent in the experience, directly perceived, without any inductive process, without the psychophysical goal, to determine any thresholds starting from the physical stimulus.

In the chapter entitled *Carl Stumpf: Founder of Experimental Phenomenology*, Spiegelberg (1965) clarifies the differences between Stumpf and Brentano:

> By phenomena (*Erscheinungen*), in general, Stumpf understands the objective correlates of Brentano's psychical phenomena or acts, or, as he is now going to call them, "psychical functions" (*psychische Funktionen*), (…). In contrast to Brentano, he does not deny reality to these phenomena but emphasizes that as contents they are as real as are the functions. Whether or not they can also exist independently of these functions, Stumpf does not want to decide in advance. While he sees no logical contradiction in such an existence, he does not subscribe blindly to the naive realism of our uncriticized beliefs. The decision as to this point has to be left to the physical sciences. - By "primary phenomena", Stumpf understands those contents of our immediate experience which are given to our senses (*Sinneserscheinungen*); by "secondary phenomena", he means the images of these as they occur in memory (1965, p. 59).

Furthermore, the phenomenological goal of Brentano was well defined by Carl Stumpf (1907) as structural law. According to Stumpf, the universal laws, which respect the character of necessity, have the form "if…then". Within "sciences of laws", he distinguishes between causal and structural laws. If sciences such as physics or physiology assume causal relationships among variables, experimental phenomenology assumes variables on the same phenomenal plane, where structural dependencies are possible without causal relationships. Then, cognitive functions are not the cause to the phenomenal world of sounds or colors.

With the same perspective of the antipsychologism of Meinong (1903), according to Stumpf (1892), the phenomenal world can be epistemologically autonomous, with its own laws, *iuxta propria principia*:

> Phenomenal facts are given with their own properties; they are in front of us as something objective, with their own laws (…)" (1907, p. 30).

The structural laws are a theoretical expression of immediate perception, of dependencies under observation; but they must have also a nomological value. Stumpf (1907) writes as follows:

> The property of which we speak on necessary judgments in logical meaning […] is a property immanent of the judgment, *regarding its content*, i.e. the state of things. The property belongs to the content and not to the act of judgment. Thus, in this respect, we are justified also to consider it as objective, that is, independent with regard to the act of present and individual judgement" (1907, p. 41).

Fig. 1 Wertheimer's law of similarity.

Therefore these laws have, in a logical meaning, a character of necessity but they regard a generalization *a parte objecti*, and then they are objective. Although these laws have a logical form, they have also an immanent *status*. The concept of phenomenal necessity (the *requiredness*) was theoretically developed afterward by a pupil of Stumpf, namely, Wolfgang Köhler (1938).

Having defined the specific character of structural laws, now we can clarify that in perceptual research, it is possible to distinguish two levels of generalizations. The first one is the law, which regards only directly observable terms. A simple example is the Wertheimer's law of similarity. Dots with the same color are spontaneously grouped (Figure 1).

This perceptual law does not require any hypothetical terms. All terms of this law (dots, similarity, and grouping) are under observation. Conversely, on the second level of generalization, theories include also hypothetical terms. An example here is the dynamic theory of the perceptual field, according to which,

> The order of facts in a visual field is to a high degree the outcome of [a dynamic] self-distribution of processes (Köhler, 1947, p. 78).

The dynamic theory implies the concept of force that is not directly perceived in the perceptual organization of the Wertheimer configuration (Wertheimer, 1923). The high generalization is an essential stage of the scientific procedure because it firstly allows explicating phenomena and it is also the heuristic instrument for new discoveries. This said, within the study of perception, the perceptual laws anyway have their own cognitive autonomy.

Precisely because perceptual laws have all terms under observation and they do not require hypothetical terms, these laws are isolated systems. Then, it is possible to test these laws without considering any logical connection with other assumptions, other theories, with a system of background knowledge. As a consequence, Duhem's thesis does not compromise the application of the *experimentum crucis* within Experimental Phenomenology of perception.

A good example of *experimentum crucis* was used by Kanizsa (1968) to study the perception of stratification in the third dimension. It is well known that two overlapping chromatically homogeneous figures are perceived as stratified in depth (Figure 2a). According to the perceptual Petter's law (1956), "the figure requiring the longer length of modal contour for its completion will appear in front".

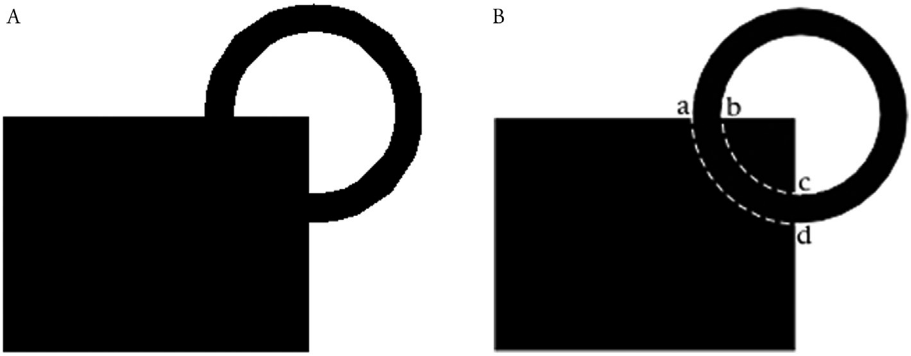

Fig. 2 **a)** The ring is perceived complete behind the rectangle. **b)** The modal contours ab and cd, to complete the rectangle, are shorter than ad and bc, to complete the ring.

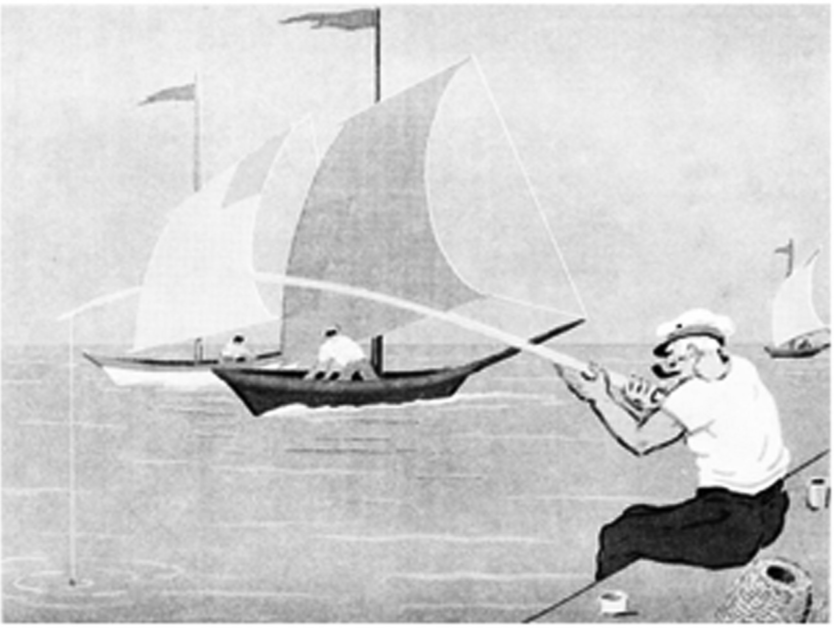

Fig. 3 The fishing rod is perceived behind the sailing boat.

This law (T1) can be forced against other perceptual constraints, such as pictorial information of depth perception (T2), e. g., perspective, relative size, height on the horizontal plane, and so on. Then, a conflict of two rival perceptual terms can be empirically presented by an *experimentum crucis*. According to Petter's law, in Figure 3, the fishing rod is perceived in front of the sailing boat (c1); according to pictorial information, the fishing rod is perceived behind the sailing boat (c2). The figure Y is the empirical contrast of c1 against c2.

In Figure 2b, c1 prevails and then T1 prevails. All terms of the demonstrative experiment (the distances of amodal contour of the fishing rod and the sailing boat; the distant position of the sailing boat; the close position of the fishing rod; the perception of complete fishing rod; and the perceptual stratification) are under observation. This is a valid perceptual demonstration under the schema of *experimentum crucis*.

In the same way, it is possible to set up an *experimentum crucis* to test the cause of perceptual stratification, in which T1 and T2 are considered, by the introduction of hypothetical terms, observable consequences c1 and c2 of other theories (T21 and T22), on a second level of generalization. According to Kanizsa (1968), T21 may be the immediate perception (which is based on the perceptual laws) and T22 may be the empiricist conception (which is based on past experience). But, as Kanizsa highlights, this *experimentum crucis* is impossible. In fact, past experience implies hypothetical terms, such as memory traces or elaboration of perceptual cues. These terms imply other assumptions and a system of background knowledge. Then, Duhem's thesis excludes, in this case, the application of the *experimentum crucis*. And here, it does not matter whether T21 and T22 are not a logical disjunction. In fact, the past experience (T22) always works. Likewise, it does not matter if it is an omnipresent explanative factor, as past experience cannot be tested.

3. Conclusion

In physics, the *experimentum crucis* cannot decide between two rival hypotheses, because theories are necessarily connected with a system of background knowledge. However, in the study of perception, in particular within Experimental Phenomenology, this methodological instrument works because perceptual laws can be isolated systems of terms under observation.

But another conclusion can be made here. To the extent that physics, and all scientific disciplines that have a high degree of theoricity, are empirical, they require the immediate perception as assumption, in any case, even if the observation is very indirect; indeed, when scientific observation needs an instrument, the instrument still needs to be read (Sinico, 2012). As has been said, any physical theory is true only if all assumptions are true. Therefore, the *corpus* of valid phenomenal laws is an unavoidable premise to the checking of any scientific theory.

Summary

This paper examines the *experimentum crucis* under the light of the Duhem's holistic thesis. This methodological instrument is not usable in physics, because physical theories

are always logically connected to many assumptions. On the contrary, it is usable in psychological research oriented to perceptual laws, when these laws are, without any hypothetical term, isolated systems. An application of *experimentum crucis* in Experimental Phenomenology of perception is presented. In conclusion, the role of perceptual knowledge as an essential assumption in other scientific disciplines that have a high degree of theoricity is also underlined.
Keywords: Duhem's thesis, *experimentum crucis,* psychology of perception, Experimental Phenomenology, perceptual laws.

Zusammenfassung

In diesem Beitrag wird das *Experimentum Crucis* im Licht von Duhem´s holistischer Theorie untersucht. Dieses methodologische Instrument ist in der Physik nicht zu gebrauchen, da physikalische Theorien immer logisch auf viele Annahmen bezogen sind. Dagegen ist es in der nach Wahrnehmungsgesetzen ausgerichteten psychologischen Forschung dann brauchbar, wenn diese Gesetze isolierte Systeme ohne irgendeine fiktive Dauer sind. Ein Anwendungsbeispiel des *Experimentum Crucis* wird aus dem Bereich der experimentellen Phänomenologie der Wahrnehmung präsentiert. Abschließend wird die Rolle des Wissens um Wahrnehmung als wesentliche Voraussetzung in anderen wissenschaftlichen Disziplinen mit hohem theoretischem Anteil unterstrichen.
Schlüsselwörter: Duhem-These, *Experimentum Crucis*, Wahrnehmungspsychologie, experimentelle Phänomenologie, Wahrnehmungsgesetze.

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