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100 years of psychology of concepts: the theoretical notion of concept and its operationalization

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Abstract

The operationalization of scientific notions is instrumental in enabling experimental evidence to bear on scientific propositions. Conceptual change should thus translate into operationalization change. This article describes some important experimental works in the psychology of concepts since the beginning of the twentieth century. It is argued that since the early days of this field, psychologists' theoretical understanding of concepts has been modified several times. However, in all cases but one, these theoretical changes did not translate into changes in the operationalization of the notion of concept learning.

Keywords: Psychology of concepts; Concept learning; Operationalization

1. Introduction

Among other things, science is remarkable for its relation to experience: at least in principle, scientific propositions are, directly or indirectly, confronted with experience. An important aspect of this relation to experience is the operationalization of theoretical notions. Although nobody believes any longer that theoretical notions are operationally defined, specifying how a theoretical entity can be detected or how a theoretical magnitude

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can be measured in an experimental setting is essential to bringing experience to bear on theoretical propositions.

These trivialities are true in psychology as well as in other sciences. In their classic 1955 paper, Cronbach and Meehl highlight the importance of the notion of construct validity (Cronbach & Meehl, 1955). In psychology, construct validity measures the extent to which the operationalization of a theoretical construct corresponds to this construct. For instance, a personality dimension, such as neuroticism, might be a theoretical construct and might be measured by means of a questionnaire. In such a case, construct validity assesses the extent to which a given score on this questionnaire corresponds to a given degree of neuroticism. How are we supposed to bring about construct validity? Construct validity depends on the (maybe sketchy) theory that involves the theoretical construct: the proposed operationalization of the theoretical construct should covary with the operationalizations of the constructs that are believed to covary with the theoretical construct under consideration. As a result, different conceptualizations of a theoretical construct should correspond to different operationalizations (ibid., p. 297). This approach has an important consequence for theoretical change. *Theoretical change should translate into operationalization change*. Or, to put it differently, operationalization change should track theoretical change. I call this principle '*the principle of operationalization change*'.

In this article, I argue that the principle of operationalization change has been repeatedly violated in a field of experimental psychology—the psychology of concepts. Since the early days of this field, at the end of the nineteenth century, psychologists' theoretical understanding of concepts has been modified several times. However, as we shall see, in all cases but one, these theoretical changes did not translate into changes in the operationalization of the notion of concept learning. I show that since the dismissal of the introspective approach to concepts, psychologists have constantly relied on the same operationalization of the notion of concept learning.

To support my contention, I single out and describe some important pieces of experimental work on concepts since the very beginning of the twentieth century. I focus on their experimental design in order to highlight the permanence of the operationalization of the notion of concept learning. Additional pieces of work that rely on similar experimental designs and operationalizations are also mentioned.

Besides exposing a deep-rooted continuity of the operationalization of concept learning, an additional goal of this article is to shed some light on the first decades of the psychology of concepts. Cognitive psychologists, developmental psychologists and neuropsychologists often know little about the psychology of concepts before the cognitive revolution. Textbook chapters on the psychology of concepts[1] as well as the main scientific reviews of the field[2] mention rarely, if ever, any article or monograph written before the 1950s. This silence suggests that there was little research on concepts before this period or, maybe, that the research on concepts before the 1950s is not of much interest. As we shall see, however, the psychology of concepts predates the 1950s. It was already part

[1] Osherson & Smith (1995), Ch. 1; Ormrod (1999), pp. 244–258; Gleitman, Fridlund, & Reisburg (1999), pp. 353–355; Medin, Ross, & Markman (2001), Ch. 10.

[2] Smith & Medin (1981); Komatsu (1992); Goldstone & Kersten (2003). Murphy (2002) is an exception: in Chapter 2, Murphy briefly discusses some major works on concepts done in the first half of the twentieth century; however, he does not mention the work on concepts by introspective psychologists.

and parcel of the introspective psychology at the beginning of the twentieth century, and it survived the behaviorist revolution.

Here is how I will proceed. In Section 2, I briefly describe the contemporary psychology of concepts and the emergence of this field at the end of the nineteenth century. In the following sections, I describe some selected pieces of experimental work on concepts. I highlight the theoretical notion of concept, the operationalization of the notion of concept learning, and the experimental design used by the psychologists under consideration. In Section 3, I focus on a piece of experimental work on concept in the introspective tradition in experimental psychology, Fisher's 1916 monograph. In Section 4, I turn to an important monograph on concepts in the functional tradition in psychology, Hull's 1920 monograph. In Section 5, I consider Smoke's 1932 experimental work, which belongs to behaviorism. In Section 6, I describe one of the most important articles in the recent cognitive psychology, Rosch and Mervis's 1975 article. In the last section, I discuss the main conclusions that emerge from this brief survey of the psychology of concepts in the twentieth century.

2. What is the psychology of concepts?

2.1. Contemporary psychology of concepts

The psychology of concepts is an important field in contemporary cognitive psychology (Smith & Medin, 1981; Murphy, 2002; Machery, Forthcoming; for a shorter review, see Goldstone & Kersten, 2003). Developmental psychologists[3] and, more recently, neuropsychologists[4] are also actively contributing to this field. Psychologists are interested in the cognitive structures that underlie our capacities to categorize, make inductions, draw analogies, and so on. Roughly, concepts are assumed to be the bodies of knowledge that are stored in long-term memory and that are used by default by our cognitive processes when we categorize, make inductions, understand languages, draw analogies, etc. (Machery, 2005, Forthcoming, Ch. 1). For instance, a concept of dog is a body of knowledge about dogs that is used by default when we categorize objects as dogs, when we reason about dogs, when we understand sentences that contain 'dog', and so on. Various types of concepts have been studied in the contemporary literature, including concepts of classes of physical objects (animals, artifacts . . .), concepts of substances, concepts of events, and abstract concepts. The properties of concepts are assumed to explain the properties of our categorization decisions (e.g., how we decide whether something is a dog), of our reasoning (e.g., how we reason about dogs), and so on. Thus, one of the leading psychologists in the psychology of concepts, Lawrence Barsalou, writes:

> Following psychological theories, we assume that *a concept, roughly speaking, is knowledge about a particular category* (e.g. birds, eating, happiness). Thus knowledge about birds represents the bodies, behaviors and origins of the respective entities. Knowledge plays a central role throughout the spectrum of cognitive activities. In on-line processing of the environment, knowledge guides perception, categorization and inference. In off-line processing of non-present situations, knowledge

[3] For instance, Carey (1985); Spelke, Breinlinger, Macomber, & Jacobsen (1992); Bloom (2000), Ch. 6; Mandler (2004); Gelman (2004).

[4] For instance, Caramazza & Mahon (2003); Thompson-Schill (2003).

> reconstructs memories, underlies the meanings of linguistic expressions, and provides the representations manipulated in thought. (Barsalou, Simmon, Barbey, & Wilson, 2003, p. 84)

In contemporary cognitive psychology, a theory of concepts focuses particularly on four questions:

1. What type of knowledge is stored in concepts?
2. How are concepts used by cognitive processes?
3. How is our knowledge stored? Is it stored in images, in words, etc.?
4. How do we acquire concepts?[5]

It is assumed that despite the obvious differences between concepts and between kinds of concepts, a unique theory can encompass most, if not all, concepts—this is what I have called 'the Natural Kind Assumption' (Machery, 2005, Forthcoming, Ch. 3). That is, it is believed that most concepts store the same type of information, are used in a similar way (at some level of abstraction), and so on.

2.2. Psychology of concepts at the end of the nineteenth century and at the beginning of the twentieth century

Few psychologists of concepts and philosophers of psychology interested in concepts seem aware of the history of the field. Although the current psychological notion of concept is imbued with the core ideas of cognitive psychology, psychologists' interest in categorization and concept learning is not new. The first section of Fisher's monograph (Fisher, 1916, pp. 2–32) provides a useful entry point to the early psychological literature on concept and concept learning (see also Moore, 1910, pp. 76–115). She correctly notes that philosophical speculations about concepts paved the way for the experimental work in psychology. Indeed, Berkeley's, Hume's or Kant's speculations about general ideas or concepts are echoed in theoretical controversies in psychology during the second half of the nineteenth century, for instance in Wundt's (e.g., Boring, 1950) or in Taine's work (e.g., Taine, 1870). However, there is little experimental work on concepts before the end of the nineteenth century. At the end of the nineteenth century, two experimental approaches to concepts emerge. On the one hand, Ribot (1891, 1899) focuses on the content of consciousness while reading or hearing a word (see also Binet, 1903). On the other hand, at the beginning of the twentieth century, there is a growing body of experimental research on how we acquire concepts from encountering category members and how we apply these concepts (Grünbaum, 1908; Moore, 1910; Fisher, 1916). To use a modern vocabulary, the two experimental traditions focus respectively on linguistic understanding and concept learning. Noticeably, these two traditions still structure the contemporary psychology of concepts (see, for instance, Murphy, 2002).

In this article, I focus on the second tradition, concept learning and categorization. As we shall see in the next sections, as a result of their theoretical commitments, introspective psychologists, functional psychologists, behaviorists, and cognitive psychologists have built different theories about the nature of concepts. However, all use the theoretical term

[5] There is a growing interest in a fifth question: how are concepts realized in our brain?

'concept' to refer to that which is acquired from encountering category members, and which enables us to decide whether entities belong to a given category. They are interested in understanding the process of learning—often called 'abstraction'—as well as the end product of this process—the concept itself.

3. The introspective psychology of concepts: Hull (1920)

3.1. Fisher's monograph

I first consider a monograph published in 1916 by the psychologist Sara Carolyn Fisher in *Psychological Monographs*. This monograph is called 'The process of generalizing abstraction; and its product, the general concept'.[6] To my knowledge, this is the first experimental work on concepts that uses what has become the most common design in the psychology of concepts. Moore (1910) briefly describes, but does not implement, this design:

> I . . . thought of exposing to a subject a series of drawings. Each drawing would represent a single object, *e.g.*, a series of net-veined or parallel-veined leaves. The subject's task would be to pick out the common characteristic. Dr. Thorndike, of Columbia University, recently told me that he had thought of the same experiment . . . (Moore, 1910, pp. 116–117)

This quotation suggests that before 1910, the experimental design used by Fisher had not been yet implemented.[7]

Another, somewhat less important, reason to focus on this work is that, to my knowledge at least, Fisher's monograph is the last experimental study on concepts in the tradition of introspective psychology (for earlier works, see Grünbaum, 1908; Moore, 1910). It epitomizes the research interests of introspective psychologists interested in concepts. Fisher's work is also frequently mentioned in later, post-introspective research on concepts (e.g., Smoke, 1932, p. 1).

In this monograph, Fisher sets out to study how people abstract concepts. She lists the following research interests:

> Our endeavor has been to throw some light upon the following questions: What are the events which transpire in an observer's consciousness after he has been confronted with a task whose successful performance necessitates the acts of generalizing abstraction? *What is the form in consciousness of the general concept?* Does this form vary, in proportion to the age and deep-rootedness of the concept? Does there exist in any or all observers a specific consciousness of generality or of universality, when dealing with features which appear in every member of a group of objects? Do there exist marked individual differences in abstracting and in concept-form? If such differences exist, in what do they consist? (Fisher, 1916, p. 1; my emphasis)

Fisher's work falls squarely in the tradition of introspective psychology. She is interested in what it is for subjects to consciously grasp a concept. And she relies on introspective reports as her experimental tool. A large part of her monograph—76 out of 209 pages

[6] The work was done in 1912–1913.

[7] I have found Fisher's design neither in the monographs and articles I surveyed nor in Moore's and Fisher's reviews of the empirical literature.

of text—presents the introspective reports of her subjects. Surprisingly, there is no mention of the decade-long controversies about the nature of consciousness and the validity of introspection as an experimental method (Wozniak, 1993).[8]

3.2. The theoretical notion of concept

The notion of concept is used by Fisher to refer to the conscious mental content that is experienced when one grasps what characterizes a class of objects. Acquiring a concept consists in forming this mental content. Thus, Fisher writes:

> The problem was now [in the seventeenth century] that of *what mental content is present when universal concept or general or abstract idea is thought*. It is this problem which has continued down to the present, and with which our present interest is mainly concerned. (Fisher, 1916, p. 16; my emphasis)

In her review of the large speculative and much smaller experimental literatures on concepts and abstraction, Fisher distinguishes two traditions. Some theorists propose that a concept of a given class is an experienced disposition to act in a given way when one encounters the members of this class, for instance, an experienced disposition to utter the word 'dog' when one meets dogs. Others propose that a concept of a given class is a conscious representation of the class—be it an image or an imageless mental representation. Fisher summarizes this distinction as follows:

> The widest differences of opinion exist as to the nature of the general concept. The two most fundamentally different groups of theories are the motor and the cognitive—those, on the one hand, which find the essence of the concept *in a motor phenomenon or tendency, with or without a conscious co-efficient of kinaesthesis or feeling*, and, on the other hand, those which attempt to envisage the concept *in ideational terms*. Many writers have, implicitly or explicitly, recognized both the motor and the ideational factors. Wide differences of opinion exist regarding the imaginal or cognitive form in which the concept appears to consciousness. (Ibid., p. 30; my emphasis)

In spite of these differences, concepts are experienced mental contents in both traditions.

Noticeably, other introspective psychologists share Fisher's characterization of the notion of concept. For instance, Moore writes:

> The botanist examining a set of specimens will classify them according to certain characteristics which mark off the genera and species. *The group of characteristics constitutes what may be termed his concept of the genus of species that he has segregated*. . . . Such 'concepts,' whatever may be their real nature, are *facts of conscious experience*; we form them and use them incessantly. (Moore, 1910, p. 74; my emphasis)

[8] The design described below is not the only experimental design in the introspective tradition. As we saw, some psychologists were more concerned with the understanding of general terms. Subjects were asked to introspect their consciousness while understanding a word (e.g., Ribot, 1891; Binet, 1903; for a review, see Moore, 1910, pp. 78 ff.).

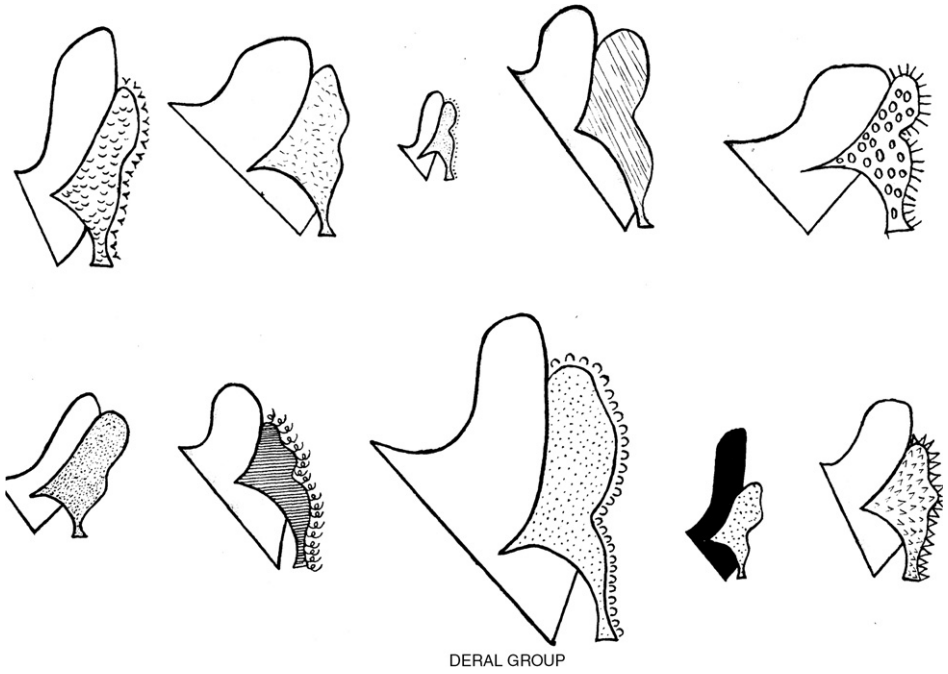


Fig. 1. An example of Fisher's stimuli, the Deral Group; the original is colored (from Fisher, 1916, Appendix).

3.3. Operationalization of the notion of concept learning

Fisher's experimental paradigm is 'genetic' (Fisher, 1916, p. 34), meaning that it focuses on the acquisition of the concept, by contrast to studying concepts that are already possessed. In more modern terms, Fisher focuses on concept learning. Great care is taken to develop some experimental materials, 'which should be optimal for introspection—in order that the observer might be able to furnish a complete and detailed introspective description of its behavior and of the mental components involved' (ibid.). Fisher creates several drawings of abstract shapes (Fig. 1).[9] Categories of ten figures are created. All the figures of a given category share a common part, which defines the category. A meaningless name—'Zalof', 'Deral', 'Tefoq', and 'Kareg'—is associated with each category. In contemporary psychology, such categories are said to be 'artificial'. Although this distinction is not always explicit in the psychological literature, there are two types of artificial categories. First, a category is artificial if it is made of particulars that are abstract figures, drawings, and so on. Fisher's categories are of this type (see also Figs. 2–4). Second, a category is artificial if it cross-cuts the category distinctions made by people. For instance, a category that would include camels, ostriches, crocodiles, mice, sharks, and eels would cross-cut the distinctions between categories that most of us make.[10] Moreover, Fisher's

[9] Moore (1910) uses also abstract shapes.

[10] However, these animals belong to the same category of clean animals in the Leviticus (for discussion, see Murphy & Medin, 1985).

categories are 'classical': there is a necessary and sufficient condition of membership, since all category members, and only them, have a part in common.

Subjects are successively presented with the members of a given category. They are supposed to examine these category members in order to be able to provide a definition for the category name, that is, to determine what part is necessary and sufficient for being a member of the category. Subjects are asked to introspect their inner life during the experiment. The exact instructions are the following:

> You are to be shown a series of ten drawings of figures which represent a group or species. The group name will be shown with every drawing; it is Zalof (or Deral, etc.). These drawings do not represent real objects; they are to be regarded merely as drawings. Do not attempt to associate them with familiar objects but confine your definition to what is shown. If such associations occur spontaneously, however, do not inhibit them. Each drawing will be exposed for three seconds, when it will be followed immediately by another. After all have been exposed, you will be given the task of defining the group name, Zalof (or Deral, etc.). You will be asked to furnish detailed introspective accounts not only of your experiences during the examination of the series, *but also of the mental processes involved in defining the group name*. (Ibid., p. 36; my emphasis)

A week after this first stage of the experiment, memories of the category members are probed. Moreover, subjects are again presented with the members of the category at hand and are asked to define the category name. The process is repeated every week *until no change is made to the definition*.

Although Fisher does not use the distinction between a theoretical notion and its operationalization, it is easy to identify what counts as having learned a concept in her study. Subjects are viewed as having learned the concept of the artificial categories under consideration *if they do not modify their conscious definition of these categories*—that is, their conscious grasp of the properties that are necessary and sufficient to belong to these categories—*when they are presented again with the members of these categories*. To put it a bit differently, having learned a concept of a category is operationalized by reference to the stability of subjects' conscious knowledge of the properties that characterize this category.

4. The functional psychology of concepts: Hull (1920)

4.1. Hull's monograph

I turn now to a monograph written by the famous psychologist Clark L. Hull, 'Quantitative Aspects of the Evolution of Concepts'. It was published in 1920 in *Psychological Monographs*.[11] Various reasons motivate the choice of this monograph. First, its author. As is well known, Clark Hull (1884–1952) has been one of the leading behaviorist psychologists in the first half of the twentieth century, working mostly on animal learning (Hull, 1943). The monograph under consideration is based on Hull's 1918 Ph.D. thesis at Wisconsin (Hull, 1920).

[11] This work started in 1912 (Hull, 1920, p. 2).

The second reason for singling out this monograph is that, to my knowledge, Hull (1920) is the first experimental study on concept learning that relies on behavioral data.[12] He distances himself from the work on concept abstraction done in the introspective tradition. He writes:

> The problem of generalizing abstraction has itself been directly attacked a number of times, notably by Moore in 1905, by Grünbaum in 1906–1907, and by Miss Fisher in 1912–1913. But in every case the studies have been *largely introspective in method, analytic in purpose, and qualitative in result*. The functional and quantitative aspects of the problem remain untouched. (Ibid., p. 1; my emphasis)

Finally, in the psychology of concepts, Hull's monograph was extremely influential. In this field, it seems to have been a turning point toward behavioral, quantitative studies. This monograph has often been quoted. It is discussed by Kuo (1923), Gengerelli (1927), and Smoke (1932). Smoke writes:

> Like the present investigation, these studies [Hull, 1920, Kuo, 1923, Gengerelli, 1927] involved the use of an objective technique. Hull's study is easily the most outstanding of these. . . . Viewed as a study of abstraction, Hull's monograph is perhaps the best thing we have. It is too well known to call for detailed treatment here. (Smoke, 1932, p. 2)

It is also one of the few empirical works on concepts in the first half of the twentieth century mentioned in the contemporary psychology of concepts (e.g., Mervis & Rosch, 1981, p. 90; Murphy, 2002).

In this monograph, Hull sets out to characterize the quantitative aspects of the abstraction of a general concept from its instances. He is interested in how the abstraction process is affected by how we encounter the instances of a concept. Different ways of encountering the instances of the concept to be learned are thus compared in a series of twelve experiments. To put it in modern terms, Hull is interested in the existence of order effects in concept learning.

Hull is not explicit about his theoretical commitments in his 1920 monograph. He seems to be influenced by the functional approach in psychology (e.g., Angell, 1907; Wozniak, 1993). He insists on the functional consequences of possessing a concept—that is, how the possession of a concept affects our behavior—and blames previous studies on concepts for having neglected these consequences. He introduces his study as follows:

> *The functional and quantitative aspects of the evolution of concepts* are at present in about the same state as were corresponding aspects of memory when Ebbinghaus published his monograph on that subject in 1885. (Hull, 1920, p. 1; my emphasis)

He may also have been influenced by Thorndike's approach to psychology (e.g., Thorndike, 1911). Hull mentions two of Thorndike's books in his bibliography (out of seventeen works mentioned). Like Thorndike, he emphasizes quantitative and objective measures, by contrast to introspective reports. Other aspects of Thorndike's method are echoed in Hull's work (Thorndike, 1911; Bitterman, 1969). Hull insists on minimizing the influence

[12] Of course, the importance of quantitative methods had been increasingly recognized since the beginning of the century in other fields of psychology.

of the observer and emphasizes concept learning situations that are similar to real-world situations. Noticeably, there is no reference to Watson in Hull's monograph, suggesting, maybe, that Hull had not yet been influenced by the early steps of behaviorism.

4.2. The theoretical notion of concept

Hull does not define explicitly what he means by 'concept'. He frequently calls the part that is common to the members of a given experimental category 'the concept of the category' (e.g., Hull, 1920, p. 10; see Fig. 2). This is misleading: the concept is not the part itself, but what subjects acquire as a result of encountering the members of a category, which have a part in common. Since Hull insists on the functional aspects of acquiring a concept, that is, on how acquiring a concept affects our behavior, including our linguistic behavior, one could suggest that for him a concept is a mere disposition to react in a given way to a class of entities that have a part in common. Textual evidence suggests however that this is not exactly Hull's notion of concept. He describes the typical process of concept learning as follows:

> A young child finds himself in a certain situation, reacts to it by approach say, and hears it called 'dog.' After an indeterminate intervening period he finds himself in a somewhat different situation, and hears that called 'dog.' . . . Thus, the process continues. The 'dog' experiences appear at irregular intervals. The appearances are thus unanticipated. They appear with no obvious label as to their essential nature. This precipitates at each new appearance a more or less acute problem as to the proper reaction. . . . Meanwhile the intervals between the 'dog' experiences are filled with all sorts of other absorbing experiences which are contributing to the formation of other concepts. At length the time arrives when the child has a 'meaning' for the word dog. *Upon examination this meaning is found to be actually a characteristic more or less common to all dogs and not common to cats, dolls and 'teddy bears.' But to the child the process of arriving at this meaning or concept has been largely unconscious*. (Ibid., pp. 5–6; my emphasis)[13]

This quotation suggests that for Hull as well for Fisher, a concept of a category is some conscious knowledge of the criteria of membership in this category. The main difference between Fisher and Hull is that for Hull, the process of acquiring the conscious knowledge that constitutes a concept is mostly unconscious. Hence, introspective reports are of little use for characterizing concept learning.

4.3. Operationalization of the notion of concept learning

I turn to Hull's experimental design, particularly in the first experiment (ibid., pp. 22 ff.). Hull creates twelve categories of twelve particulars (ibid., pp. 9 ff.; see Fig. 2). These particulars are slightly deformed Chinese characters. A meaningless sound, for instance 'oo' or 'yer', is associated with each category: it is the name of the category. Like Fisher's categories, Hull's categories are classical: there is a necessary and sufficient condition of

[13] Hull also writes: 'where the common element is seemingly very simple *it may come to consciousness* only in the most halting and gradual manner' (Hull, 1920, p. 80; my emphasis).

Fig. 2. Hull's twelve categories and twelve packs of deformed Chinese signs (from Hull, 1920, p. 10).

membership (ibid., p. 13). Like Fisher's categories, these categories are also artificial: their members are meaningless, perceptual forms.

Twelve packs made out of one instance of each category are constituted (see Fig. 2). The order of the instances in these packs is randomized. The first experiment tries to determine whether it is simpler to acquire a concept 'by experiencing first the simpler concrete examples from which it is to be abstracted and proceeding progressively to the more complex and difficult examples, over an opposite order' (ibid., p. 9).[14] The procedure of the first experiment is the following (ibid., pp. 9 ff.). The members of each pack are presented successively for five seconds. The experimenter utters the name of the category the instance belongs to after two seconds and a half. Subjects have to utter the name of the category before the experimenter, if they are able to do it. Otherwise, they repeat the name uttered by the experimenter. This is supposed to endow concept learning with a function—bringing about correct naming. The same pack is presented repeatedly up to a perfect performance.[15] Then, the experimenter presents the instances of the next pack. Six packs are used to allow subjects to abstract the concepts of the twelve categories. Hull comments on the instructions as follows:

> In the instructions, all suggestions of abstraction of common elements, generalization of definition were studiously avoided. Positively he [the subject] was led to

[14] Experiments B–D test various hypotheses concerning the effect found in Experiment A. The other experiments vary the presentation of the category members.

[15] In Experiment C, packs are presented a fixed number of times.

> believe that he was about to do a kind of memory experiment. He was told that he would be prompted in the middle of each exposure, that he should repeat the syllable[16] each time when prompted and that as soon as possible he was to react before prompted.[17] This process was continued with the first 'pack' until all the reactions were perfected . . . At the beginning of the second 'pack' the subject was told in a matter-of-fact way that the second set would easier because the same names would be used as with the first set, so there would be no new names to learn. Just before exposing the first character, he was told to see how many of the new characters he could 'guess' correctly before being prompted. This injunction to 'guess' was given at the beginning of each succeeding series. (Ibid., p. 15)

The six remaining packs are used to test to which extent subjects have learned the concepts of the twelve categories. The members of each pack are presented successively. Subjects are asked to utter the name of the category each figure belongs to. This is the test phase.

Four measures are made. The number of errors made in the test phase is the main measure. It measures the extent to which the concept of each category has been abstracted. It is said to be 'a thoroughly convenient and adequate functional measure of the perfection of a concept' (ibid.).[18] The number of correct category names uttered before the experimenter at the first presentation of each pack and the number of promptings necessary to perfect the reaction to each pack are also measured. Finally, a qualitative measure, which is said to be 'not functional', is also made: the capacity to draw the common character.

The main measure suggests that the operationalization of concept learning can be characterized as follows. A subject has perfectly learned the concept of one of the twelve experimental categories *if and only if she is able to categorize correctly all the new items she is presented with in the test phase of the experiment*. The number of errors indicates the extent to which she has learned the concepts: a subject's number of errors in the test phase measures the imperfection of her learning. The two other functional measures are consistent with this interpretation of the operationalization of concept learning. The last measure is used by Hull to show that during learning, subjects' introspective grasp of the part that is common to the members of an experimental category is not a good measure of concept learning.

It is clear that Hull's operationalization of concept learning differs from Fisher's operationalization. Concept learning is not operationalized by Hull by reference to what subjects are able to say, that is, by reference to what they explicitly know about the category at hand. Instead, concept learning is operationalized by means of subjects' performance in a categorization task.

5. The behaviorist psychology of concepts: Smoke (1932)

5.1. Smoke's monograph

I focus now on Kenneth Ludwig Smoke's monograph, entitled 'An objective study of concept formation', which was published in *Psychological Monographs* in 1932.[19] By 1932,

[16] That is, to repeat the name of the category, 'oo', 'yer', etc.
[17] That is, to name the category the stimulus belongs to.
[18] This measure is still used in the contemporary psychology of concepts.
[19] This monograph is based on Smoke's dissertation for his Ph.D. in 1931 at Ohio State University.

behaviorism was the dominant paradigm in American experimental psychology. Behaviorist ideas had been very quickly applied to the psychology of our higher cognitive functions, as illustrated by the title of Zin Yang Kuo's 1923 study, 'A behavioristic experiment on inductive inference'.[20] The psychology of concepts is no exception (Gengerelli, 1927).[21]

Smoke's monograph has not been chosen for its experimental quality. It is mostly inconclusive. The data are often insufficiently clean to be statistically analyzed (Experiments 1 and 2). Most results are null effects (Experiments 2 and 3). The author even recognizes that little is learned by his experiments (e.g., Smoke, 1932, p. 30). It is nonetheless interesting in several respects. First, because of its commitment to behaviorism. Although Smoke is not a militant behaviorist, he endorses the behaviorist terminology and principles.[22] For instance, when he introduces the notion of 'insightful behavior' (ibid., p. 35), he justifies this term as follows:

> We employ 'insightful behavior' in preference to 'insight' because it is a descriptive phrase that avoids the suggestion of faculty psychology. From one point of view, an individual exhibits 'insightful behavior' when he makes complex discriminative responses which he could not make a relatively short time before, his physiological condition having remained relatively constant. (Ibid., n. 10)

Despite the obscurity of the second part of this quotation, the idea is rather simple: by 'insightful behavior', Smoke means a response that is not predicted by previous responses.

Smoke's monograph is also interesting because of its main topic. Smoke focuses mostly on the importance of negative instances in concept learning—what we would today call 'negative evidence'. The role of negative evidence in concept learning has been an important topic in the second half of the twentieth century. To my knowledge, Smoke introduces this research issue.[23]

5.2. The theoretical notion of concept

In behaviorists' work on concepts, a concept is defined as a disposition to associate category members with a given behavior, preferentially with a linguistic behavior—that is, a disposition to utter the name of the category when one encounters the members of this category (e.g., Kuo, 1923; Gengerelli, 1927; Smoke, 1932). Acquiring a concept consists in learning the correct association between a class and a response, for instance, naming. Smoke writes:

> By 'concept formation,' 'generalization,' or 'concept learning' we refer to the process whereby an organism develops *a symbolic response (usually, but not necessarily, linguistic) which is made to the members of a class of stimulus patterns but no to other stimuli.* (Smoke, 1932, p. 8; my emphasis)

The mentalistic component of the notion of concept, which was present in Fisher and, arguably, in Hull, has entirely disappeared. Smoke refers instead to the 'unknown' 'neuromuscular and neuroglandular events that occur in the formation of any given concept' (ibid.).

[20] Kuo's experiment is to some extent an experiment on concept learning.
[21] For the sake of space, I will not discuss here the field of concept learning in behaviorist animal psychology.
[22] Nonetheless, he presents some introspective reports in Experiments 3 and 4 (Smoke, 1932, pp. 31 ff.; pp. 37 ff.).
[23] Kuo (1923) had already studied the importance of negative instances, but in a different context.

5.3. Operationalization of the notion of concept learning

The stimuli used in Smoke's experiments are ten classes of sixteen meaningless visual stimuli (Fig. 3). Each class is defined by a specific definition that is satisfied by all and only its members. A meaningless syllable is associated with each class: It is the name of the class. For instance, the syllable "dax" is associated with a class that is defined as follows:

> A 'dax' is a circle and two dots, the one dot being inside the circle and the other outside it. (Ibid., p. 13; see the top left of Fig. 3)

Members of the dax class differ in terms of size, color of the circle, width of the line, color of the dots, and so on. For each class, negative stimuli are also created. Each of these stimuli violates the definition of the relevant class in one respect. For instance, for the class of 'dax', a negative stimulus could be a circle with two dots inside (see the second figure at the top left of Fig. 3). The classes used by Smoke are both artificial and classical. They are made of meaningless figures and are defined by a necessary and sufficient condition of membership.[24]

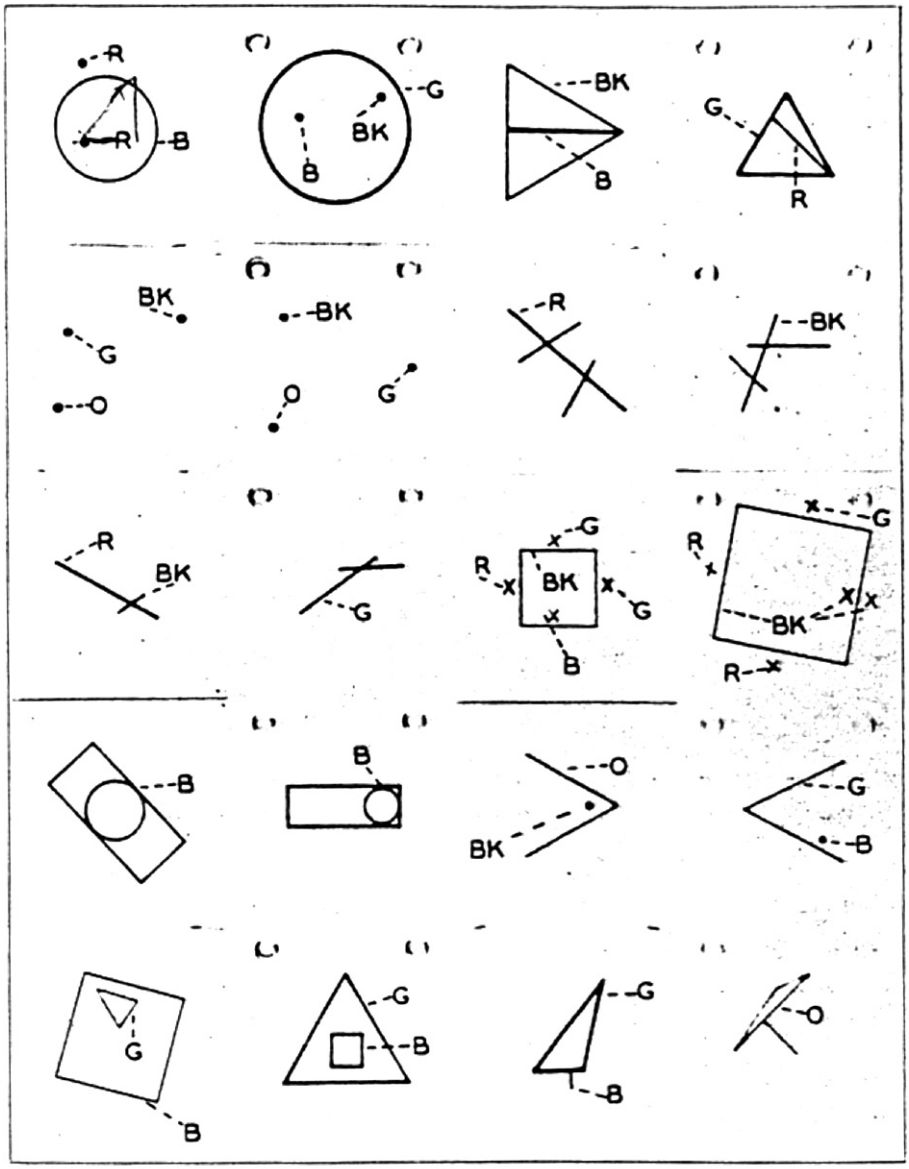
The experimental design is the following. In Experiment 1, subjects are presented with sixteen members of a given class, say the dax class. Daxes are presented successively, one every three seconds.[25] The subjects' task is to find out the membership condition in the class. Subjects stop the presentation of figures when they think they have found out the membership condition. For Experiment 1, subjects are given the following instructions:

> You will see a series of figures (or drawings) each and every one of which is called a 'dax'—DAX, 'dax.' Try to fund out everything a figure must be if it is to be called a 'dax.' I shall illustrate what I mean.
>
> You will recall that until recent years there were no 'chairs' in Japan. Even today there are residents of parts of Japan who have never seen what we call a 'chair.' Let us imagine one of these people coming to America. He has to learn, along with many other things what a 'chair' is. You are in much the same situation, except that instead of learning what a 'chair' is you will learn what a 'dax' is. When you think you know what a 'dax' is, raise your hand. (Ibid., pp. 17–18)

Smoke uses three tests to decide whether a subject has really learned the concept of the category at hand (ibid., p. 15). First, subjects are asked to define verbally the class. They are given the instruction: 'Please, state what a ____ is.' Second, subjects are asked to draw members of the class. They are given the instruction: 'Please draw two ____.' Finally, they are shown sixteen drawings and they have do decide which of them are members of the relevant class and which are not. Half of these drawings belong to the class. Only the third test is used to decide whether subjects have learned the concept. Subjects are given the following instructions:

[24] The condition of membership differs in Smoke's study and in Fisher's and Hull's experiments. In the latter experiments, the condition of membership is a part of the members of the classes. This is not the case in Smoke's experiments (Smoke, 1932, p. 16). Smoke views this as a major innovation of his study.

[25] In the three other experiments, subjects are presented also with negative instances.



Speciments of Designs used in the Experiments

Fig. 3. Examples of Smoke's category members and of figures that fail to satisfy a category definition (from Smoke, 1932, plate between pp. 12 & 13).

Here is a series of sixteen drawings. Some of these drawings are ____s and some of them are not. If the drawing is a ____ write 'Yes' after its number. If it is not a ____ write "No.' If you should happen to change your mind as to what a ____ is, be sure to stop and change your definition. (Ibid.)

If a subject makes no mistake, she is considered as having learned the concept. The next class is then presented. If a subject makes some mistakes, she is presented with the remainder of the category members. If the subject has not learned the concept at the end of the experiment, the presentation of the category members is repeated. The time needed to learn the concept of the category is measured as a dependent variable. It is taken to be 'the best available measure of the difficulty of the concept and of the speed with which the subject learned it' (ibid.).

Smoke's operationalization of concept learning is similar to Hull's operationalization: a subject is viewed as having perfectly learned the concept of a category *if and only if she correctly categorizes new items in this category*. Thus, Smoke writes:

> In this study, . . . we count the subject as having learned a concept if he is able to go faultlessly through a test series of sixteen stimulus patterns, some of which fulfill the conditions of the concept in question and some of which do not. (Ibid., p. 9)

6. The cognitive psychology of concepts: Rosch and Mervis (1975)

6.1. Rosch and Mervis's article

It is sometimes suggested that cognitive psychologists and behaviorists have little in common. However, this is incorrect, at least in the field of the psychology of concepts. In fact, cognitive psychologists interested in concepts have used and still use experimental designs that are similar to the designs used by behaviorists, functional psychologists and introspective psychologists.

In this section, I focus on Eleanor Rosch and Carolyn B. Mervis's famous article, 'Family resemblances: Studies in the internal structure of categories', published in *Cognitive Psychology* in 1975.[26] Rosch's work, including this article, played a crucial role in the rejection of what is known as 'the classical view of concepts', according to which a concept consists of a definition—that is, a set of necessary and jointly sufficient conditions of membership (Smith & Medin, 1981; Murphy, 2002). Moreover, she significantly contributed to the formulation of the prototype approach to concepts. Finally, this article decisively contributed to establishing what are sometimes called the typicality phenomena—that is, the correlation between typicality and various properties of our categorization decisions. I focus on the fifth experiment (Rosch & Mervis, 1975, pp. 592 ff.).

6.2. The theoretical notion of concept

In the article under consideration, Rosh and Mervis do not use the theoretical notion of concept and, *a fortiori*, do not define this notion. Indeed, they explicitly refrain from proposing a specific model of representations and of cognitive processes. They propose instead that their results constrain these models (ibid., p. 600). It is however clear that Rosch and Mervis endorse implicitly the standard notion of concept in cognitive psychology (see also Rosch, 1975). This notion has been well described by Smith and Medin:

[26] Other classic experiments in the psychology of concepts rely on similar designs (Bruner, Goodnow, & Austin, 1956; Posner & Keele, 1968, 1970; Medin & Schaffer, 1978; Nosofsky, 1986).

> To have a concept of X is to know something about the properties of entities that belong to the class of X, and such properties can be used to *categorize* novel objects. (Smith & Medin, 1981, p. 8; see also Section 2 above)

This notion of concept contrasts sharply with Smoke's behaviorist notion of concept: concepts are thought of as bodies of knowledge, not as mere dispositions to have a given overt behavior in response to a class. Despite some similarities, this notion is not identical to Fisher's and Moore's notion of concept, for this knowledge does not have to be conscious.

6.3. Operationalization of the notion of concept learning

In Experiments 5 and 6, Rosch and Mervis want to establish that there is a correlation between how quickly we learn the membership of items in a given category (rate of learning), how fast we are at deciding whether items belong to a given category (latencies of categorization decisions), and the typicality of category members. Rosch and Mervis write:

> In the two following experiments [5 and 6], artificial categories were constructed in which items differed only in the degree of family resemblance within categories or amount of overlap of attributes between categories. In these experiments, the structure[27] was provided as an independent variable; our hypothesis was that this structure would affect rate of learning of category items; reaction time in judging category membership once the categories were learned; and ratings of prototypicality of items. (Rosch & Mervis, 1975, p. 591)

Experiment 5 focuses on family resemblance. Family resemblance is, roughly, defined as follows. If an item possesses few properties that are shared by other members of its category, but many properties that are possessed by few members of its category, this item has a low degree of family resemblance. On the contrary, if an item possesses many properties that are shared by other members of its category, and few properties that are possessed by few members of its category, this item has a high degree of family resemblance.

The stimuli consist of strings of five letters and numerals, such as 'HPNWD' and '4KCTG' (ibid., pp. 592–593). Each category consists of six strings (Fig. 4). For each category, the degree of family resemblance of its members is computed in a straightforward way. Each letter receives 'a weight representing the number of strings in the category in which it occurred' (ibid., p. 592). For each string, the weights of its letters are summed. Like in the experiments reviewed in the previous sections, categories are artificial, made of meaningless items. However, they are not classical: there is no necessary and sufficient condition of membership.

The experimental procedure is the following. Three family resemblance structures are defined. In the first one (called 'control set'), all items have the same degree of family resemblance. In the second one ('symmetric experimental set'), two items have the same maximal degree of family resemblance, two items have the same intermediate degree, and two items have the same lowest degree. In the last family resemblance structure ('asymmetric experimental set'), the degree of family resemblance decreases for each item (for more details, see ibid., pp. 592–594). Ten categories were used for each family resemblance structure.

[27] See below.

TABLE 3
ARTIFICIAL CATEGORY STRUCTURES USED IN EXPERIMENTS 5 AND 6

		Type of category structure							
		Control set			Symmetric experimental set			Asymmetric experimental set	
Use of the category	Item in category	Letter string	Family resemblance score	Overlap score	Letter string	Family resemblance score	Overlap score	Letter string	Family resemblance score
Basic category structure	1	HPNWD	12	0	JXPHM	15	0	DLT83	16
	2	HPNSJ	12	2	XPHMQ	19	1	DLT8A	15
	3	GKNTJ	12	4	PHMQB	21	2	DLTPM	14
	4	4KCTG	12	5	HMQBL	21	3	DLGKI	12
	5	4KC6D	12	3	MQBLF	19	4	D9H60	10
	6	HPC6B	12	1	QBLFS	15	5	3YH7V	7
Nonoverlap contrast category (Experiment 5)	1	R7QUM	12		CTRVG	15		SXB25	16
	2	R7QXV	12		TRVGZ	19		SXB2Q	15
	3	Z5Q2V	12		RVGZK	21		SXBRE	14
	4	L5F27	12		VGZKD	21		SXVFW	12
	5	L5F1M	12		GZKDW	19		S4Z1&	10
	6	R7F19	12		ZKDWN	15		5JZCN	7
Overlapped contrast category[a] (Experiment 6)	1	8SJKT		4[b]	GVRTC		0		
	2	8SJ3G		3	VRTCS		1		
	3	9UJCG		3	RTCSF		2		
	4	4UZC9		2	TCSFL		3		
	5	4UZRT		3	CSFLB		4		
	6	MSZR5		3	SFLBQ		5		

[a] Overlap is with the basic category structure not the nonoverlap contrast category.
[b] Contrast strings in control do not have same structure as initial category strings and were not analyzed in Experiment 6.

Fig. 4. Rosch and Mervis's stimuli in Experiments 5 and 6 (from Rosch & Mervis, 1975, p. 593; reprinted from *Cognitive Psychology, 7*, E. Rosch & C. Mervis, Family resemblances: Studies in the internal structure of categories, 573–605, copyright 1975, with permission from Elsevier).

Participants are told that they have to learn to distinguish two categories, category one and category two. They are first presented with the six members of category one, then with the six members of category two. Then, the twelve strings are mixed and their order is randomized. The strings are successively presented and participants have to classify them. They get a positive or negative feedback until they achieve two errorless runs. This ends the learning phase. A test phase follows. It consists in categorization decisions under time constraint. Participants are asked to categorize, as quickly as possible, the twelve strings that were used during the learning phase. Reaction time is measured. Participants have also to rank order the typicality of each string.

Thus, the operationalization of concept learning can be characterized as follows. A subject is said to have perfectly learned a concept *if and only if she makes no mistake in categorizing the training items at the end of the training phase*. This is obviously similar to Hull's and Smoke's operationalizations. Subjects' performances in a categorization task operationalize concept learning. The only difference consists in the nature of the items used in the categorization task. While Hull and Smoke use new items, Rosch and Mervis use the training items.

7. Discussion

In this section, I discuss two main points—the reliance on similar experimental designs all along the history of the psychology of concepts and the relations between the theoretical notion of concept and the operationalization of the notion of concept learning.

7.1. The concept learning design

Despite some differences, it is plain that Fisher (1916), Hull (1920), Smoke (1932), and Rosch and Mervis (1975) use similar experimental designs.[28] I call this type of experimental design 'the concept learning design'. For the sake of space, I do not discuss in detail the myriads of variations on the basic structure of this type of experimental design.

The point of this experimental design is to study concept learning (also known as concept abstraction). Concept learning consists in forming a concept on the basis of encountering some members of the represented category—that is, learning what it is to belong to this category or, as behaviorists would put it, acquiring a disposition to associate a response to this category. The four experimental studies discussed in this article are all concerned with the properties of concept learning.[29]

In the concept learning design, the categories that are to be learned are usually artificial—in the sense that they are made of meaningless items (abstract figures, strings of letters, etc.). Usually, category members are merely characterized by perceptual properties (see Figs. 1–3 above).[30] Artificial categories are thought to enable psychologists to control the variables that affect concept learning and, thus, to test hypotheses about the process of concept learning. Moreover, when subjects have to learn the concepts of artificial categories made of meaningless figures, their background knowledge does not influence their performances. Thus, differences between subjects in background knowledge are controlled.[31] Finally, artificial categories can be specifically designed to test competing theories of concept learning.[32]

The concept learning design includes a learning phase. During this phase, participants are presented with some members of the category(ies) to be learned. The task is to find out what distinguishes category members from items that do not belong to the category. This task can be explicit (e.g., Fisher, 1916) or implicit (e.g., Hull, 1920). Category members can be presented in many different ways. Usually (but not always, see Fisher, 1916), some properties of the learning phase are measured as dependent variables (Hull, 1920; Smoke, 1932; Conant & Trabasso, 1964; Rosch & Mervis, 1975). Duration and the number of errors are the most common dependent variables.

Often, but not always, a distinct test phase follows the learning phase. The test phase consists in ascribing the learning items (Rosch & Mervis, 1975) or new items (Hull, 1920) to the category(ies) that were used in the learning phase. Various dependent variables can be measured. The most common ones are reaction time (e.g., Rosch & Mervis, 1975, Experiment 5) and the number of errors.

[28] A related design has been used in animal psychology to study visual discrimination and in the psychology of vision to study form recognition.

[29] To mention a few classic papers, see also Bruner, Goodnow, & Austin (1956); Medin & Schaffer (1978); Nosofsky (1986).

[30] See also Gengerelli (1927); Conant & Trabasso (1964); Posner & Keele (1968,1970); Medin & Schaffer (1978); Nosofsky (1986).

[31] This methodological point has been criticized in the recent psychology of concepts.

[32] Note that the categories used in the concept learning design are not necessarily classical (e.g., Rosch & Mervis, 1975; Medin & Schaffer, 1978).

7.2. The theoretical notions of concept and the operationalizations of concept learning

Three main notions of concept emerge from the four studies reviewed above. Fisher and Moore propose that a concept is a conscious mental content that is experienced when one grasps what characterizes a class of objects. Despite its emphasis on the functional aspects of concept possession, Hull seems to endorse a notion of concept that is similar to introspective psychologists' notion. Smoke and other behaviorists propose a radically different notion of concept. A concept is not a piece of knowledge, but merely a disposition to behave in a specific way, particularly to utter a name, when one encounters the members of a given class. Rosch, Mervis, and other cognitive psychologists endorse a notion of concept that is, in some respects, closer to introspective psychologists' notion of concepts than to behaviorists' notion. A concept is a piece of knowledge about a category that can be used to categorize objects in this category. In line with the cognitive revolution, cognitive psychologists assume that this knowledge is not necessarily conscious.

The theoretical changes from the introspective notion to the behaviorist notion of concept and from the behaviorist notion to the cognitivist notion of concept did not translate into changes in the operationalization of the notion of concept learning. The only substantial change in the operationalization of this notion took place in Hull's monograph. While Fisher operationalizes concept learning by reference to subjects' explicit knowledge of the membership conditions in the relevant category, Hull and most psychologists after him operationalize this notion by reference to subjects' categorization performances: subjects are said to have learned the concept under consideration if and only if they are able to categorize correctly the learning items (Rosch & Mervis, 1975) or new items (Smoke, 1932). Divergence from perfect categorization measures the imperfection of concept learning. This operationalization change arguably results from the increasing role of behavioral measures in the various fields of psychology as well as a growing distrust toward introspection at the beginning of the twentieth century (Wozniak, 1993). Thus, theoretical changes diverge strikingly from operationalization changes: the only clear operationalization change, which took place in Hull's monograph (1920), corresponds to a (probable) case of theoretical continuity, while the clear theoretical changes correspond to cases of operationalization continuity.

What should we conclude from this discrepancy? A tentative conclusion is that experiments in the psychology of concepts in the twentieth century have not borne on the specific theoretical notions of concepts endorsed by functional psychologists, behaviorists and cognitive psychologists. To put it differently, these theoretical notions have not been endorsed for experimental reasons. Instead, they result from psychologists' theoretical commitments. For instance, behaviorists endorsed a behavior-based notion of concept because of their commitment to behaviorism. They use this notion to interpret the findings from experiments on concept learning, but these experiments could be interpreted by means of cognitive psychologists' notion of concept, since behaviorists and cognitive psychologists share the same operationalization of the notion of concept learning.

8. Conclusion

Clearly, a lot of work remains to be done to get a clearer picture of the history of the psychology of concepts. Only the tip of the iceberg has emerged in this article. However, we can already draw three substantial conclusions. First, the psychology of concepts does

not appear for the first time in the 1950s. Like contemporary psychologists, introspective psychologists, functional psychologists and behaviorists focused on the process by which we learn to distinguish the members of a category from the non-members—concept learning—and on the end product of this process—the concept. The theoretical term 'concept' is used to refer to that which is learned from encountering category members and which enables us to decide whether entities belong to a given category. At the beginning of the twentieth century, introspective and functional psychologists moved beyond the theoretical speculations in philosophy and in psychology to gather some experimental evidence bearing on the nature of concepts and of concept learning.

Second, and more importantly, psychologists of concepts have been using similar experimental designs to study concept learning since the beginning of the twentieth century. I have called this type of experimental design the concept learning design. This design can, of course, be implemented in various ways. However, its general structure is easy to detect in the experimental studies presented in this article as well as in many classic articles on concepts.

Finally, and most importantly, the principle of operationalization change has been repeatedly violated. That is, successive theoretical changes did not translate into different operationalizations. The notion of concept is spelled out differently in the different research traditions of the twentieth century. It is a conscious mental content for introspective psychologists and, arguably, for functional psychologists such as Hull, an association for behaviorists, a typically unconscious body of knowledge for cognitive psychologists. Despite these theoretical changes, the only clear operationalization change takes place in Hull's monograph—before the development of behaviorism in the psychology of concepts. Thus, typically, experiments on concept learning in the twentieth century—the main tool in the psychology of concepts—did not reflect the theoretical changes in the understanding of concepts and, as a result, did not bear on these theoretical changes.

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