

Charles van den Heuvel

Royal Netherlands Academy of Arts and Sciences, Huygens Institute for the History of the Netherlands. The Hague, Netherlands

Multidimensional Classifications: Past and Future Conceptualizations and Visualizations

Abstract: This paper maps the concepts “space” and “dimensionality” in classifications, in particular in visualizations hereof, from a historical perspective. After a historical excursion in the domain of classification theory of what in mathematics is known as dimensionality reduction in representations of a single universe of knowledge, its potentiality will be explored for information retrieval and navigation of the World Wide Web.

1 Introduction

Licklider observed in his *Libraries of the Future* that most studies of topological and metric space analogies (for the greater part written in the domain of information retrieval) focused so far on linear methods. Moreover, he claimed that: ‘those studies have not emphasized the space concept, and they have led to little or no consensus even about the dimensionality, much less about the identities of the dimensions, of any such thing as “information space” or “semantic space” or the “space of knowledge”.’ (Licklider 1965, 77) We agree that such a consensus still does not exist, but state at the same time that in the history of classification the concepts space and dimensionality were explored. Although conceptualizations of space and dimensionality in the organization of knowledge are much older we start our historical exploration in 19th century with three interrelated debates: on the classification of the sciences, on evolution and on atomist theory. Conceptualizations of dimensionality can be traced in the history of classification of the sciences. For instance Herbert Spencer in his criticism on the linear and historical sequential representation of the evolution of the sciences by the positivist thinker Auguste Comte, argued that sciences are so complex that the relationships only can be explained in a multidimensional way. (Spencer 1864, 26) The discussion on the evolution of the sciences stood in a wider context of the 19th century debate on (biological and organic) evolution. After Darwin’s publication of *On the Origin of Species* in 1859, the idea that life had evolved in a process of natural selection became particularly an active source of academic debates focusing on the philosophical, social and religious dimensions of the evolution of human life. Studies in the emerging discipline of psychology (Baine, Wundt, Fouillée, Bergson) tried to include the evolution of mental order and explored the internal dimension or “psyche” of man. Related to these discussions on the classification of the sciences and of evolution, there was a third debate that focused on the origin and substance of the universe (atomism). Since the atomic theory that John Dalton formulated in his *A New System of Chemical Philosophy*, that appeared in the years 1808 and 1810, the debate on atoms and voids in the universe got a new impetus. At first sight this debate seems remote from classification in library science. However, the 19th century developments in astronomy had both an impact on the library sciences via the old metaphor of the universe of knowledge and via new notions of time and space in atomic theory.

In other studies we discussed considerations on space and multidimensionality of classificationists such as Richardson, Otlet, Bliss, Ranganathan and their historiographers Miksa and Beghtol who used the universe of knowledge metaphor in their debates on hierarchy and flexibility in their strive to promote their classification system and to develop a new classification theory. (Heuvel and Smiraglia 2010; Smiraglia and Heuvel 2011) In another study we focused in particular on multidimensionality in visualizations of universes of knowledge. (Heuvel and Akdag 2011, in press)

We also briefly explored the potential impact of atomic theory on the UDC and observed that the pioneer of documentation Paul Otlet followed the debates on astrophysics of the beginning of the 20 century closely. Although we concluded that new views on “spacetime” did not lead to change of the UDC it was argued that Otlet was nevertheless aware of the contradiction with his separation of space and time in his classification system, which he hoped would be solved with further advancements in mathematics. (Heuvel and Smiraglia, 2010) Moreover, other phrases in his publication *Monde* of 1935 suggest that Otlet was interested in the spatial consequences of the developments in atomic theory. He observed that since the theories of Riemann and Einstein another “hypergeometrie” should be considered, and suggested a new discipline of “spatiologie.” (Otlet 1935, 304-306) Otlet did not explain further what he intended with these new disciplines of hypergeometry and spatiology, but unpublished manuscripts in the archives of the Mundaneum reveal that he was studying the implications of spacetime and notions of events in the work of Samuel Alexander, Bertrand Russell and Alfred North Whitehead for synthesis of knowledge. Although these new notions of space (and time) did not have an impact on the UDC, unpublished drawings in the abovementioned archives reveal that multidimensionality and space played a crucial role in Otlet’s first conceptualizations of classification. We will compare some drawings in this manuscript of Otlet to the mappings of Ranganathan of a multi –dimensional universe of knowledge along a one-dimensional space (line) (Ranganathan 1967, 382). Finally, the notions of dimensionality in “intellectual space” of the ignored theorist of classification Gérard Cordonnier will be discussed.

After this historical excursion in the domain of classification theory of what in mathematics is known as dimensionality reduction in representations of a single universe of knowledge we try to explore its potentiality for information retrieval and navigation multiple universes or multiverse of knowledge. We argue that Otlet’s and Ranganathan’s mappings of multi-dimensional knowledge spaces on a one-dimensional one or line in combination with the development of a viewer based on parallel vision of documents developed for Nelson’s XanaduSpace can be useful to retrieve knowledge classes in formal ontologies and folksonomies and their contexts from different perspectives. On the basis of predictive models of the future structure of the World Wide Web by Albert-László Barabási, we argue that the dream of data-integration of all knowledge seems to be even more remote than in the past, but that the development of the abovementioned viewer could be useful for information retrieval within a constellation of multiple (sub-) universes that develop in a modular and at the same time self organizing way.

2 Historical notions of multidimensionality and of space in classifications

Probably the first author who discussed the importance of these more general debates on classification of the sciences, on the evolution of mankind and the human mind and finally of the universe of knowledge for the emerging discipline of Library Science was Henry Evelyn Bliss.

(Bliss 1929) Most of the names he mentioned in his historiographical study of classifications by Bliss and have relevance for conceptualizations of space and dimensionality: the in-between spaces of Cutter's "transient classes", Richardson's historical dependency of spaces for new classes, and Sayer's observations on parallel-orders. The role of these conceptualizations was touched upon as part of the attempt for formulate a faceted classification theory, in particular in discussions on the Colon Classification by the Classification Research Group (1951) and by several authors such as S.R Ranganathan (1951,1957, 1967) Thomas Daniel Wilson (1972), Clare Beghtol (2008) Francis Miksa (1992 and 1998) and Katryn La Barre (2006). In other studies we tried to put (the self-proclaimed) role of Ranganathan in the development of the "first classification theory" in a more critical way and put it into context from a different historical perspective by comparing the CC to the UDC (Smiraglia and Heuvel 2011, 44); (Heuvel and Akdag 2011, in press). In this paper we continue our exploration of faceted classification systems. This is based on the assumption that the concepts space and multi-dimensionality play a more prominent role herein and that they are more suitable for a comparative analysis. Secondly both Paul Otlet and Ranganathan used visualizations of multidimensional aspects of their classifications which can be compared. (Heuvel 2008; Ranganathan 1967, 382; Miksa 1992, 116) Finally both Otlet and Ranganathan discussed the role of language and notation in relation to spatial sequence and multi-dimensionality in their faceted classifications. The latter issue is of importance for a comparison with discussions about logical relations between concepts and a classification (Farradane 1952, Smiraglia et al., 2011, in press) and between knowledge organization and hypertext. (Nelson and 2004; Rayward 1994)

2.1. *Multi-dimensional thought and one-dimensional arrangement*

The observation of Licklider that most studies of topological and metric space analogies focused so far on linear methods, is partly true. As we will see the mathematical method of dimension reduction was indeed applied in practical ways. Not seldom that what Licklider had called the identities of these dimensions were ignored or reduced in these very same practical applications of linear methods. "The business of the librarian and the function of library tools are to help every unit of thought –energy to reach its destiny"- Ranganathan stated in a paragraph on the purpose of classification. (Ranganathan 1951, 95) The purpose of classification is in his view a process of transformation from a multidimensional space of thought to a one-dimensional space that easier to handle and to perceive things:

"Thought is multi-dimensional. But we are one-dimensional beings – that is we still prefer all things to be handled to be arranged in one-dimension [...] This means that classification is essentially a transformation of a many-dimensional universe into a uni-dimensional, uni-directional one. The machine tools are expected to perform this transformation." (Ranganathan 1951, 96)

In his *Prolegomena to Library Classification* Ranganathan gives an example of a mapping of subjects belonging to a multi-dimensional universe into a system of points along a line. (Ranganathan 1957: 254; 1967: 382-386) He visualized the mathematical mapping of space of large number of dimensions on one of a smaller number in a so-called Apupa arrangement in the third edition of his work. (Ranganathan 1967, figs. 19, 20, 21) (See, Figure 1b)

In an earlier publication Frits Donker Duyvis, the secretary of the International Institute of Bibliography and committee member of the revision of the UDC had made clear that Ranganathan's Colon Classification was much indebted to Otlet's multi-dimensional classification. (Donker Duyvis 1951, 99) Although Donker Duyvis in his presentation of the UDC as a practical method argued that Otlet and La Fontaine never had the intention to develop it as a theory, Otlet used this term explicitly to describe his visual explorations of the multidimensional character of his classification. In his manuscript *Theorie schematique de la Classification* of 14 December 1908 Otlet describes and visualizes in so-called "schemes fondamentaux" (fundamental schemes) the multidimensional reduction of the content of various formats to one line and the recombination of these elements in multi-dimensional knowledge constructions. (See, Figure 1a) Various sources of information coming from multiple direction are brought in one line and comparable content is expressed in notations of letters a, a1, b, b, b1 etc. and combinations hereof (Figure 2). In successive pages he translates these dimensions in numerical notation of the UDC and includes sketches of multidimensional knowledge objects in which these various classes meet.

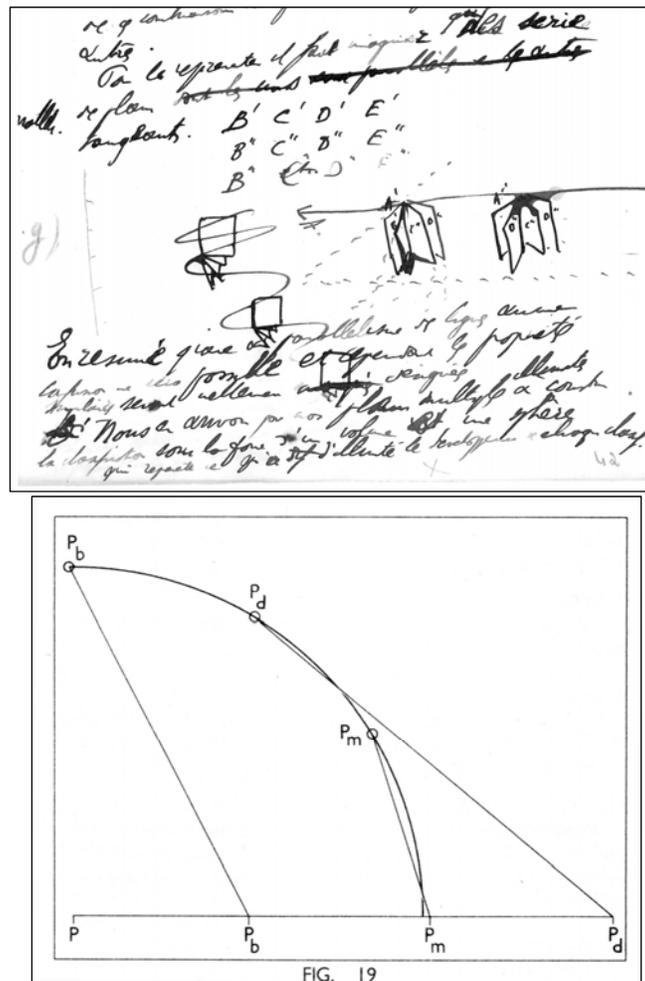


Figure 1a + b: Dimension reduction in the work of Otlet and Ranganathan
Otlet, *Theorie schematique de la Classification* of 14 December 1908

(© Mons, Mundaneum EUM Farde 9 N. 39)
Ranganathan (1967) Fig. 19

2.2 *Conceptualizations of metric and of topological space.*

Although Licklider was right in his observation that most studies of topological and metric space analogies focused on the practical application of dimension reduction in information retrieval, we do not support his argument that there were hardly conceptualizations of space and multidimensionality and their identities. We argue that as part of several attempts to formulate a classification theory conceptualizations of space and dimensionality were brought forward. Paradoxically, space and dimensions were especially discussed as part of the problem to handle time, evolution and synthesis in the development of the universe of knowledge.

When Paul Otlet and the most famous Modernist architect of the 20th century Le Corbusier together made plans for a World City on the banks of Lake Geneva in Switzerland, they designed its main building, the Mundaneum in the form of spiral to symbolize the increase and development of global knowledge. Ranganathan used a similar spiral form in a diagram that expressed the development of the universe of knowledge as a dynamic continuum (Ranganathan 1957, 250-51). The spiral is for Otlet and Ranganathan an expression of expansion of total knowledge on the long term, which encompasses (non visible) short successive cyclic movements. (Otlet 1935, 318; Ranganathan 1957, 249) Otlet as we will see called these short term cyclic movements “evenements” and Ranganathan described them as a “continuous cascade of new micro-thoughts” in the universe of knowledge. Both Otlet and Ranganathan were aware of the tensions between the factors time and evolution on the one hand and the synthesis of elements of facets of knowledge within their classification systems. In a unpublished manuscript in the Archives of the Mundaneum in Mons (Belgium) with the title “Relations fondamentales” of 9 April 1928, Otlet refers explicitly to the works of Samuel Alexander (known for this concept of bottom-up emerging synthesis) and the philosophers/mathematicians Bertrand Russell and Alfred North Whitehead who both questioned the idea of an universal synthesis and who used notions of events as occurrences. In this manuscript, that according to its subheading discusses “the philosophy and research of a new scheme (schema) of time and space”, Otlet stated that Alexander and Russell, replaced the classical view of permanent synthesis by “a collection of relative events.” Whitehead, in Otlet’s view, broke with the notion of synthesis all together. Whitehead rejected indeed the idea that each object has a simple spatial or temporal location. If he had been familiar with the work of Otlet he would probably had reckoned it to what he called in his *Science of the Modern World* of 1926: “The Fallacy of Misplaced Concreteness”, or the error of mistaking the abstract for the concrete. According to Whitehead it would be wrong to see in a spatial point more than abstraction and every real-life object may be understood as a constructed series of events:

“In a certain sense everything is everywhere at all times. For every location involves aspects of itself in every other location. Thus every spatio-temporal standpoint mirrors the world. (Whitehead 1945, 114)

Whitehead’s view that all things are in a continuously flux, is quite different from the spatio-temporal notions of Otlet and Ranganathan. Otlet in *Monde* made a distinction between a) the development of reality and b) the development of “ideas in systems and syntheses with an

assimilation and remodelling of what is new”, which c) at certain moments in time intersect at certain points. (Otlet 1935, 331) Ranganathan does follow this line of reasoning of successive syntheses in his loops of “micro-thought”. However, whereas Otlet thought that this development could be handled by an update of the UDC from time to time, Ranganathan was convinced that it implied a fundamental change in classification. The latter observed that there is “wastage incidental to ‘research in parallel’” in the development universe of knowledge that has to be eliminated “by organizing ‘research in series’.” (Ranganathan 1957, 248) To this end Ranganathan introduced “depth classification” which he defined as: “a scheme of classification fitted to reach coextensiveness and expressiveness in the classification of micro-thought having many rounds and levels of facets, and isolates of high orders in any all of them.” (Ranganathan 1957, 241)

This dept classification of microthought was in Ranganathan a strategy to prevent the reversion of research in series in research in parallel. (Ranganathan 1957, 251) However, every classification in Ranganathan’s view has its limitations. Its scheme depends on what is regarded as the minimum, essential invariant. The establishment of this invariant is a forced compromise or in Ranganathan’s words ” a scheme is obliged to do so only for the most widely used approach.” (Ranganathan 1957, 255) This does not only has implications for classification but for synthesis as well:

“Much of the difficulty, due to classification being equivalent to the mapping of a multi-dimensional space over a one-dimensional one, arises in the synthesis of the facets. If there are n facets in micro-thought, a scheme has to chose forcedly one of the $n !$ ways of arranging them in a class number.” (Ranganathan 1957, 255)

The mathematics of this mapping, Ranganathan states, has not yet been worked out in detail by anybody and for the time being he proposes a symbiosis with cataloging to overcome the limitations of classification. (Ranganathan 1957, 255) The Library Research Circle that was formed in 1951 in India, discussed every Sunday on Ranganathan’s veranda mathematical aspects of classifications. Its members modeled their approaches after Russell’s and Whitehead’s works on mathematics. (LaBarre 2006, 42) We do not know for sure whether they discussed the views of the latter on mapping of multidimensional spaces and classification as well. Whitehead links in his *Adventures of Ideas* (1933) “non-metrical projective geometry” to what he called “the science of cross-classification.” (Whitehead 1967, 137-38) Different from elementary geometry of Euclidian space, non metric projective geometry has a projective space. In this space, geometric transformations are permitted to move “points at infinity” to traditional points, and vice versa that are not permitted in Euclidian space. (Wikipedia 2011) Ranganathan’s description of how the successive isolates in a chain within a facet, considered from the angle of the idea plane, form a “Nest of Cells in many dimensions” and from the notational plane a “Nest of Intervals on a line” might have been inspired by Whitehead’s views on projective geometry. (Ranganathan 1957, 254-255) Although Ranganathan recognized the existence of a “two-fold infinity” – an infinity in the approaches of readers of documents and an infinity in the dimensions of the universe of ideas to be organized (LaBarre 2006, 43) he seems to exploit the method of projective geometry in a one directional way i.e. the transformation from more dimensions to one, or what Licklider had called the use of linear methods in information retrieval.

A forgotten classificationist, the French naval engineer and mathematician Gérard Cordonnier who was familiar with the principles of projective geometry as well, did not focus on the line but on what he called “intellectual space.” (Cordonnier 1944, 26-28) This intellectual space is constituted by a collection of logical relationships between ideas, in the same way that physical space consists of a collection between material relationships. (Cordonnier 1944, 27) He explains how a collection of relations represented as a geometrical figure can be represented from one point of view as a synthesis of all projected figures possible. In an Euclidian space the material point, - Cordonnier uses the a molécul as example - can be defined by three coordinates.

“However, if you want to go beyond that point you have to deal with the parameters that defines the relative positions of atoms and another step further more dimensions are introduced that regulate them that allow the mathematician to start his exploration. One can say that the three visual dimensions of the world ramify in each stage of a new approximation of this internal universe and becomes inseparable of time.” (Cordonnier 1944, 28)

Cordonnier distinguishes various types of ramifications that regulate the development of tree like (“arboresente”) structures of classifications. He is familiar with the UDC and stressed the potential of the alternative system of Bliss to connect his general classification with the needs of special classifications. Cordonnier, familiar with the Colon Classification edition of 1933, follows Ranganathan in his critique of the hierarchical tree-like structure of the UDC; a critique that was challenged by Donker Duyvis and more recently by Heuvel and Akdag on the basis of a visual analysis this classification system. (Ranganathan 1951, 100, Donker Duyvis 1951, 99-100, Heuvel and Akdag, 2011: in print) Cordonnier praises what Ranganathan had called the banyan tree structure of the Colon Classification which branches ramify and grow at the top and at the bottom. However, he also observes illogical orders in certain classes and notation in the Colon Classification and tries to take it further by a profound analysis and typology of developments and dimensions of the tree like structures of various classification in order to develop a new one. He states that the classificationist should not strive for giving each object or idea an unique place:

“A universal classification should be a collection ordered by points of view. An object will be found in more rubrics [classes under more subject headings] of which the whole defines its place in the intellectual domain, similar to a point in space is defined by its “coordinates” or projections according to more points of view. (Cordonnier 1944, 7)

The notation of such a class is not presented in the form of a linear string of elementary symbols, but as a branching (rameau) with branches on various levels of subdivision. He is thinking of a ramification with two branches that do not grow necessarily in the same way, since they are sometimes enriched to express an idea more precisely or abbreviated if an idea is less interesting for a specialized node. (Cordonnier 1944, 8) Such ramification is “open” if the tree-like structure develops in all directions with full independency of its branches and “cyclic” when each of its sub branches refers to the original branch from which they all stem. Cordonnier 1944, 30-32) This is quite different from Ranganathan’s projections since in the case of Cordonnier the dimension time is included in the various tree-like structures that are not only projected in, but also evolve and shape his “intellectual space.”

of referential classification, Shera argues that any single unit of knowledge may be meaningful in any number of different relationships depending upon the immediate purpose.

“Relationship is not a universal, but a specific fact unique to things related, and just as these relations reveal the nature of the relata, so the relata determine the character of the relationship.” (Shera 1951, 84)

The character of relationships in classification, and the continuous change hereof is difficult to represent. Farradane in his “scientific theory of classification” formulated this as follows: “Owing to the difficulties of representing all possible relational series in any fixed form, printed form, each classification, shows only a limited selection, which imposes a rigid network which is mostly neither adaptable nor logically true throughout.” (Farradane 1952, 75)

Farradane proposes a system of *logical relations*, which he calls operators, to be used as a basis for classification based on methods of perception rather than on philosophical views or the everyday experience of librarian. (Farradane 1952, 78) He tries to get a grip on the multidimensional complexity of relationships by representing each operator as a line that points in a different direction. The result is a complex diagram in which specific notations symbols and arrows are combined to express the multidimensional character of the combination of operators, (Farradane 1952, 85-86) (figure 3)

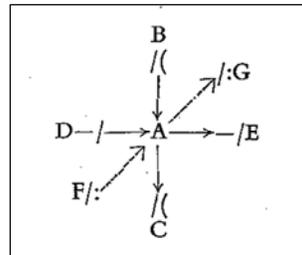


Figure 3 Farradane (1952) representation of dimensions of operators

Shera, whose choice of words strongly reflect the ideas of Whitehead, questioned the possibility of representation of logical relations in knowledge all together:

“The fallacy, of course, lay in the fact that a hierarchical structure is but one pattern of thought in a universe of infinite patterns [...] what is a rational or logical association for one can be quite irrational and illogical for another. (Shera 1957, 22)

Shera believes that there is no universal system of classification to all situations, just as there is no one pattern of human thought. (Shera 1957, 26) However, Shera does not break with classification all together; it is in his view just misapplied:

“Classification, then, can achieve its fullest purpose as instrument of bibliographic organization only after the *idea* content of the book has been dissociated from its physical embodiment –its codex form.“ (Shera 1951, 81)

The emphasis of separating “idea content” from its physical embodiment is not new and links Shera directly to Otlet’s visions of “substitutes for the book.” (Heuvel 2008, 139-141) However, Shera’s call to replace universal systems of classification by classification as a discipline based on concepts and concept formation, rather to use it as a tool is fundamentally different from all other classification constructs or “theories” so far. Shera’s description of the “future of classification” does not only differ in its emphasis on concept formation, but has far reaching implications for the role of the librarian as well, who in his view had to have knowledge of recent discoveries in physiology, psychology, cybernetics, information theory, linguistics, anthropology, sociology of knowledge, history of thought and of the basic sciences of mathematics, physics, chemistry, biology and the social sciences. He concludes : “..the librarian of the future may well be regarded as the geneticist of our intellectual life.” (Shera 1957, 26)

Shera stretched the role of classification and that of the librarian to the limit. When he wrote his paragraph on the future of classification, bibliographic organization and traditional library methods were challenged by the rapid introduction of mechanical tools that began to take over the operations of the librarian in an automated way. It is in this context as well that Licklider wrote in 1965 his essay on *Libraries of the Future*. Similar to Shera he dissociates the idea content of the book from its the book and the library as physical bodies. However, Licklider’s search of concepts and ideas behind the visible and tangible aspects of documents is not directed anymore on its implications for classification or the role of the librarian. Licklider’s focus is on “transformable knowledge” and man’s interaction with such knowledge in library systems for the future, which he prefers to define as “precognitive systems”, to reflect their role in the advancement and application of knowledge. (Licklider 1965, 6) Licklider’s shift in attention towards man-computer interaction precognitive systems has not only consequences for the conceptualization of the space which he calls the “fund of knowledge” but also of topological space and dimensionality. Licklider visualizes the changes of the fund of knowledge by comparing the information flow in existing knowledge systems and in a future simulation in which a precognitive system has been implemented. (Figure 4)

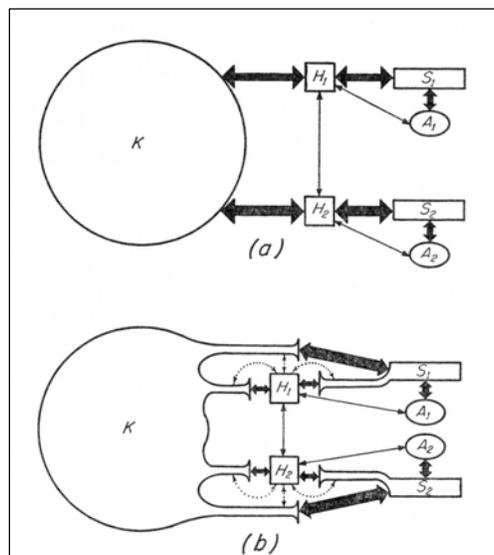


Figure 4 Licklider (1965), knowledge fund and human computer interaction before (a) and after (b) implementation of precognitive system