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«The cognitive (r)evolution». A scientometric perspective to review trends and developments in the cognitive science paradigm

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Abstract. Cognitive science adopts an interdisciplinary approach to study cognitive systems. To systematically review the cognitive science literature, two data samples were downloaded from Scopus: one regarding the whole literature on cognitive science (N = 13,414 documents) and the other including the 2000s's literature (N = 12,337 documents). A CiteSpace's Document Co-Citation Analysis (DCA) was computed on each sample. From the clusters discussion, a multidisciplinary approach emerges. Psychology, linguistics, neuroscience, computer science, anthropology, and philosophy shaped the cognitive science literature over the years. Particularly, the clusters identified in the sample from 1977 to 2021 showed a strong emphasis on cognitive theories and models. Conversely, the clusters identified in the 2000s' literature had a stronger emphasis on a physiologically based approach. Our analysis highlights two relevant aspects in cognitive science: (i) the multidisciplinary nature of the field; and (ii) how technological advances reoriented the field toward a more physiologically oriented approach.

Keywords: cognitive science, document co-citation analysis, scientometrics, multidisciplinary approach, bibliometric limitations, citation bias, database dependency.

Introduction

The term cognitive science encompasses several disciplines aimed at studying the architecture and the functioning of biological and artificial cognitive systems (Nadel & Piattelli-Palmarini, 2003; Gentner, 2019).

Cognitive science is notably interdisciplinary and, since its beginning, it involves six main disciplines: psychology, linguistics, neuroscience, computer science, anthropology, and philosophy (Miller, 2003).

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Historically, the "cognitive revolution", to cite Miller's words (2003), started as a response to behaviorism. Specifically, the behaviorist manifesto claimed that only behaviors should be the focus of experimental psychology. Since little was known on what happens inside the organism, behaviorists banished internal states and representations from experimental psychology (Nadel & Piattelli-Palmarini, 2003). The focus on observable and measurable behaviors would have allowed, in the behaviorists' minds, researchers to turn psychology into an objective science. From the works of Chomsky on natural language, cognition and mental processes became the focus of experimental psychology once again (Miller, 1956). In the same period of time, cybernetics and artificial intelligence were under development and the use of computers to simulate cognitive processes was gaining momentum (Minsky, 1961; Newell & Simon, 1972).

The aforementioned scientific contributions converged on 11 September 1956 in a pivotal symposium organized at the Massachusetts Institute of Technology. Many refer to this specific event as the birth date of cognitive science (Gardner, 1987; Miller, 2003).

The current paper intends to provide insights into the field of cognitive science in two ways. First, by identifying the most influential and impactful documents in the cognitive science literature. Second, by examining the main thematic trends of research that have shaped the scientific literature on cognitive science. Impactful publications and research thematic domains were examined both with regards to the whole literature on cognitive science and to the literature of the 2000s. To do so, the current paper adopts a scientometric approach, as in previously published publications in the fields of clinical psychology, neurobiology, and parenting (Carollo et al., 2021a; Carollo et al., 2021b; Carollo et al., 2021c).

Methods

Materials

Two scientometric analyses were performed in the current paper. The first analysis examined all the scientific literature regarding cognitive science and the second one focused on the subset of scientific contributions from the 2000s. Both analyses followed the methodology adopted by previously published works (Carollo et al., 2021a; Carollo et al., 2021b; Carollo et al., 2021c). For the scientometric analysis regarding all the scientific literature on cognitive science, the Scopus platform was chosen to download the initial sample of publications, as in previous scientometric reviews (Lim et al., 2021). In order to identify the relevant documents and the scientific developments that shaped the cognitive science paradigm, all papers having the term "cognitive science" in their title, abstract, or keywords were collected by adopting the following string of keywords: "TITLE-ABS-KEY ("cognitive science") AND (LIMIT-TO (LANGUAGE,"English"))". By doing so, the downloaded data sample consisted of 13,414 publications, covering the period from 01 January 1977 to 06 September 2021 - the day in which the data collection was conducted. Data were subsequently imported in CiteSpace (version 5.8.R1), the software chosen for conducting the scientometric analysis. When importing data in CiteSpace, data irregularities typically cause small percentages of data loss (~ 1.0% – 5.0%) (Carollo et al., 2021b). These amounts of data loss are negligible and do not have a relevant impact on the subsequent results (Gaggero et al., 2020). Accordingly, a total of 767,851 references cited by the publications downloaded from Scopus were initially identified. Of the 767,851 references, 746,906 (97.27% of the total references) were considered valid by the software. Other 5,835 anonymous references (0.76% of the total identified references) were detected and removed using an ad-hoc Python script. The final amount of excluded references (n = 26,780; 3.49% of the total number of identified references) can be considered as negligible.

The same procedure was applied for the collection and management of the second data sample, the one referring to the scientific contribution of the 2000s in the field of cognitive science. Specifically, 12,337 documents were downloaded from Scoupus and the period from 01 January 2000 to 15 December 2021, the day of data collection, was covered. When importing data in CiteSpace, a total of 740,737 references were identified. Out of the total number of references, 721,120 (97.35%) were considered valid. Other 3,972 references (0,54% of the total references) were identified as anonymous by the ad-hoc Python script and were removed from the data sample. Again, the final amount of excluded references (n = 23,589; 3,18% of the total number of identified references) can be considered as negligible.

Document Co-Citation Analysis (DCA)

The aim of the research was to identify the impactful documents and the research domains in the development of the cognitive science paradigm. To do so, CiteSpace software was used to conduct a Document Co-Citation Analysis (DCA). The DCA focuses on the frequency in which two or more documents are cited together - in other words, co-cited - and generates a network of documents (Small, 1980). The generated network includes both citing and cited documents. The first ones, the citing documents, are the ones downloaded directly from Scopus platform. The second ones, the cited documents, correspond to the references identified by CiteSpace when importing the downloaded data (Carollo, Lim, Aryadoust, & Esposito, 2021). Eventually, by analyzing the patterns of co-citation between citing and cited documents, DCA allows uncovering the thematic domains that shaped the scientific literature of interest in a data-driven fashion.

Identification of the optimal DCAs

DCA's final network depends on the criterion used when selecting the nodes to include. In particular, the node selection criterion determines the strategy used to determine whether or not to include a specific document as a network node. The node selection criterion goes with a scale factor, a numerical value indicating the threshold for the associated selection strategy. To obtain the optimal DCA network, node selection criteria and scale factors were varied and the resulting DCAs were compared. Specifically, three different node selection criterion were compared in both the scientometric analysis of the current paper: g-index, TOP N and TOP N%, as in Carollo et al. [2021a; 2021b]. G-index, which is based on the h-index, represents the "largest number that equals the average number of citations of the most highly cited g publications" (Egghe, 2006). TOP N and TOP N%, on the other hand, include in the network all the N or N% most cited documents within a given time-frame. The time-frame in this study was always kept at one year.

In the analysis regarding the whole literature on cognitive science, the following DCAs were computed: g-index with k values set at 20, 25, 30, 35, 40, 45, 50, and 75, TOP N with N set at 10, 40, 45, 50, 55, 60, 65, and 100, and TOP N% with N% set at 5, and 10. By weighting its overall impact on the structural attributes of the generated network and on the overall configuration (i.e., number of clusters, number of nodes, number of links), TOP N with N set at 10 resulted to be the optimal criterion. In the analysis regarding cognitive science with a focus on the 2000s, the following DCAs were computed: g-index with k values set at 5, 10, 15, 25, 50, and 75, TOP N with N set at 5, 10, 15, 25, 50, 75, and 100, and TOP N% with N% set at 5, and 10. Again, TOP N with N set at 10 resulted to be the optimal criterion to create a balanced network.

Figure 1 summarizes the steps conducted in the current scientometric study, from the data collection to the number of references included in the final network, for both the analysis.

Metrics

Results in CiteSpace are described in terms of structural and temporal metrics.

The first group, structural metrics, includes modularity Q, silhouette score, and betweenness centrality indices. Modularity Q, whose values range from 0 to 1, indicates the degree to which a network is divisible into single groups of nodes, also known as modules or clusters (Newman, 2006). Well-structured net works typically obtain high modularity values. Conversely, silhouette scores assess the inner consistency (i.e., cohesion and separation) of the identified network's clusters (Rousseeuw, 1987). Possible values for silhouette range from -1 to 1, with higher values indicating that the cluster is highly separated from others as well as that the cluster has an high inner consistency. The last structural metric, betweenness centrality, represents the extent to which a node may function as a bridge to connect any two arbitrary selected nodes within the network (Freeman, 1977). Values of centrality range from 0 to 1, with larger values typically obtained by groundbreaking and revolutionary scientific works.

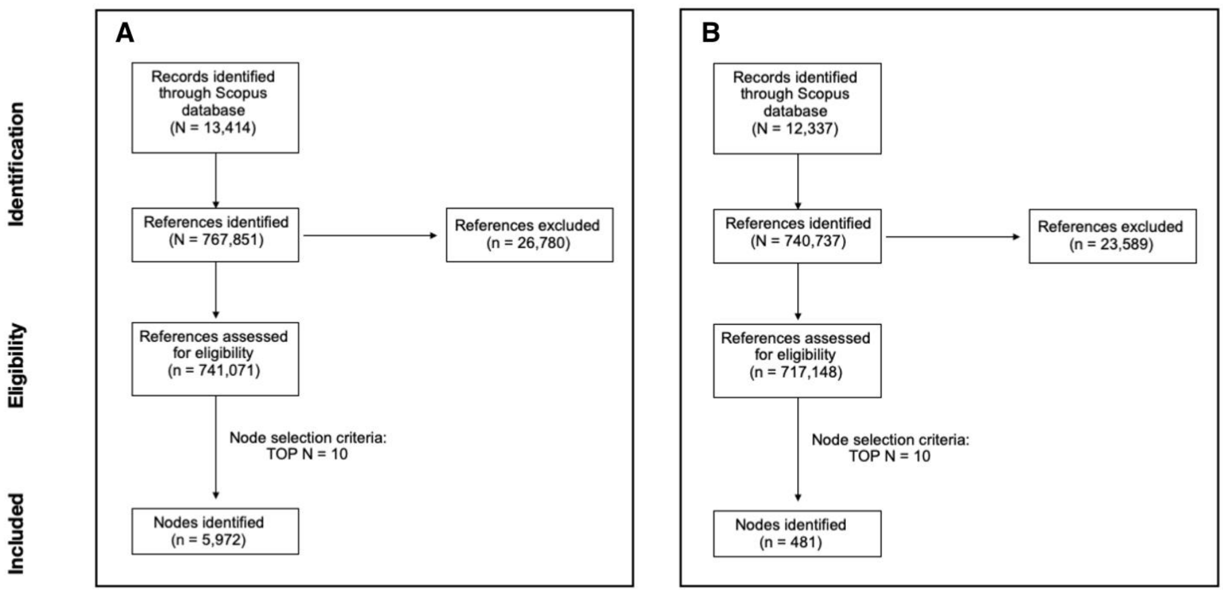

Figure 1. Study flow diagram. The initial samples of publication were obtained from Scopus using the keywords "TITLE-ABS-KEY ("cognitive science") AND (LIMIT-TO (LANGUAGE,"English"))". Data from Scopus were collected on the 06 September 2021 for the research regarding cognitive science literature from 1977 to 2021 (A). Data from Scopus were collected on the 15 December 2021 for the research on cognitive science literature with a focus on the 2000s (B).

The second group of metrics - namely, temporal metrics – includes citation burstness and sigma. Kleinberg's algorithm is used to calculate citation burstness (Kleinberg, 2003), which refers to a sudden increase in the number of citations received for a specific node in the network within a given time period (Chen, 2014).

Citation burstness values can potentially range from 0 to infinity. In contrast, Sigma is a metric that is calculated by combining betweenness centrality and citation burstness using the following equation: (centrality+1)burstness.

Sigma values indicate the novelty an influence of a node in the network of interest. The values range from 0 to 1, with higher ones typically obtained by impactful and innovative research (Chen, 2014). Influential publications have higher citation burstness and sigma (Lim et al., 2021).

Results

3.1. Cognitive science from 1977 to 2021

The DCA obtained from the analysis on all the literature on cognitive science consisted of a network of 5,972 nodes and 17,528 links. Hence, on average, each node was connected with other 2.94 nodes. The network displayed a modularity Q index of 0.9803 and a weighted mean silhouette of 0.9883. As a result, the nodes form a network that is easily subdivided into separate modules, each of which is highly consistent.

A citation burst occurred in the citation history of 63 network nodes. The strongest burst was obtained by Clark et al. (2008) (strength of burstness = 32.15; burst duration = 4 years). Thompson [21] (strength of burstness = 24.00; burst duration = 4 years) and Clark (2013) (strength of burstness = 22.95; burst duration = 4 years) authored the documents with the second and third strongest citation burst, respectively. With regards to the documents' burst duration, the publication by Pfeifer and Scheier (2001) was the one with the longest burst duration (strength of burstness = 13.67; burst duration = 5 years).

Within the DCA network, nine major clusters were identified and renamed according to their scientific content. On average, documents included in these clusters were published in the 1970s and 1980s (see Table 1 and Figure 2). Cluster #3, by including 110 nodes (1.84% of the whole network), was the largest cluster of the network (silhouette score = 0.995; average year of publication = 1982). The following clusters in terms of size were cluster #4 (size = 107; silhouette score = 1.000; average year of publication = 1979) and cluster #5 (size = 107; silhouette score = 0.952; average year of publication = 1987). Clusters #4 and #5 together covered the 3.58% of the nodes included in the network). In reference to the average year of documents publication, cluster #36 was the most recent cluster (size = 38; silhouette score = 1.000; average year of publication = 1988) and it was followed by cluster #5, #26 (size = 47; silhouette score = 0.999; average year of publication = 1986), and #51 (size = 27; silhouette score = 0.996; average year of publication = 1986).

3.2. Cognitive science with a focus on the 2000s

The analysis of the literature on cognitive science with a focus on the 2000s generated a DCA composed by 481 nodes and 980 links. Therefore, each node had, on average, 2.04 connections. The network had high modularity (modularity Q = 0.8885) and high silhouette (mean silhouette 0.9802). The metrics indicate that the network is highly divisible into homogeneous clusters.

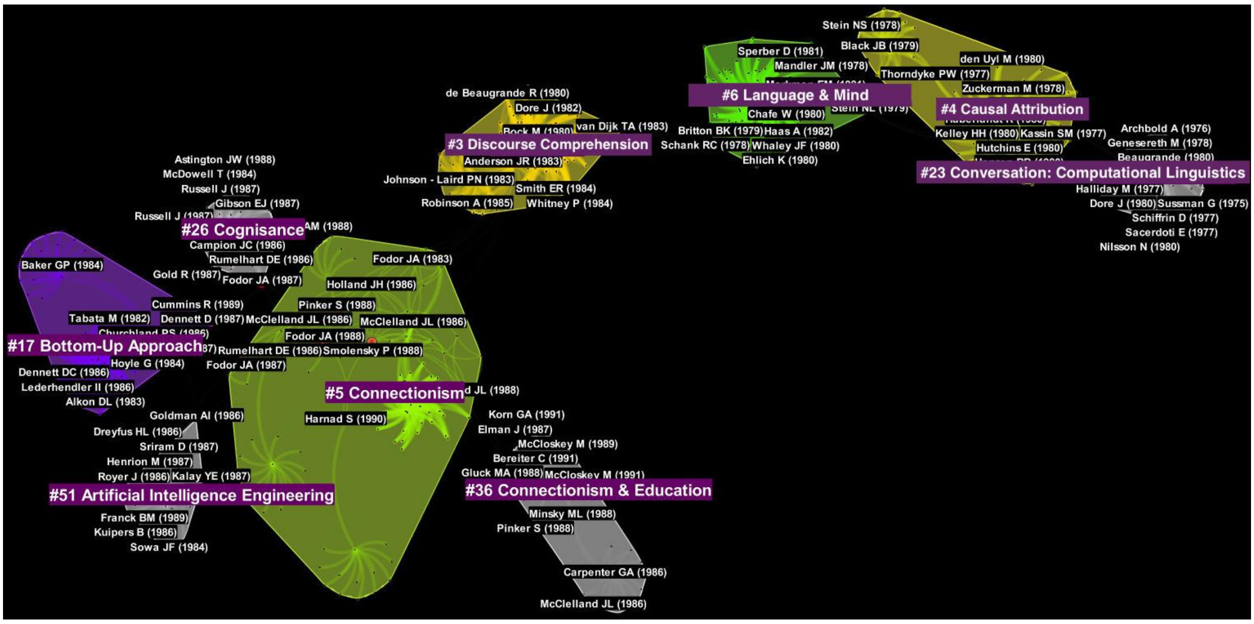

Figure 2. Network of publications generated through the Document Co-Citation Analysis (DCA) on the literature about cognitive science from 1977 to 2021. The 9 major clusters that were identified are represented by different colors.

A total of 52 references in the network reported a burst in their citation history. The strongest burst was obtained again by Clark et al. (2008) (strength of burst = 24.19; duration of burst = 4 years), which was followed by Thompson (2007) (strength of burst = 18.46; duration of burst = 4 years) and by Chemero (2011) (strength of burst = 18.09; duration of burst = 2 years). The longest burst duration was recorded by Clark et al. (2008), Thompson (2007), Clark (2013) (strength of burst = 17.94; duration of burst = 4 years) and Gallagher (2017) (strength of burst = 13.53; duration of burst = 4 years).

In the network, 8 major clusters were identified and renamed according to their content (see Figure 3 and Table 2). The largest cluster of the network, cluster #0, included 42 documents (silhouette score = 0.997; average year of publication = 2013). In terms of size, cluster #0 was followed by clusters #2 (size = 36; silhouette score = 0.969; average year of publication = 2007) and #3 (size = 33; silhouette score = 0.962; average year of publication = 2016). With regard to the average year in which documents were published, clusters #3 (size = 33; silhouette score = 0.962; average year of publication = 2016), #0, and #9 (size = 13; silhouette score = 0.967; average year of publication = 2011) were the most recent clusters. Conversely, clusters #5 (size = 18; silhouette score = 1.000; average year of publication = 2002), #13 (size = 9; silhouette score = 0.978; average year of publication = 2005), and #18 (size = 6; silhouette score = 0.989; average year of publication = 2006) were the least recent ones.

Table 1

Metrics of the 9 major clusters identified when computing the Document Co-Citation Analysis (DCA) on the literature about cognitive science from 1977 to 2021.

Cluster ID	Size	Silhouette	Mean Year	Assigned Label
3	110	0.995	1982	Discourse Comprehension
4	107	1.000	1979	Causal Attribution
5	107	0.952	1987	Connectionism
6	97	0.986	1980	Language & Mind
17	67	0.994	1984	Bottom-Up Approach
23	50	0.999	1977	Conversation: Computational Linguistics
26	47	0.999	1986	Cognisance
36	38	1.000	1988	Connectionism & Education
51	27	0.996	1986	Artificial Intelligence Engineering

Discussion: Clusters

This study aimed at examining the research trends in cognitive science under a scientometric approach. Two DCAs were computed to provide in sights into the whole literature on cognitive science and the literature of the 2000s in the field. The thematic contribution of the major identified clusters is discussed below following the chronological order of the average year in which the related documents were published. Also, similar clusters were grouped by theme. Each cluster was manually named to reflect its content.

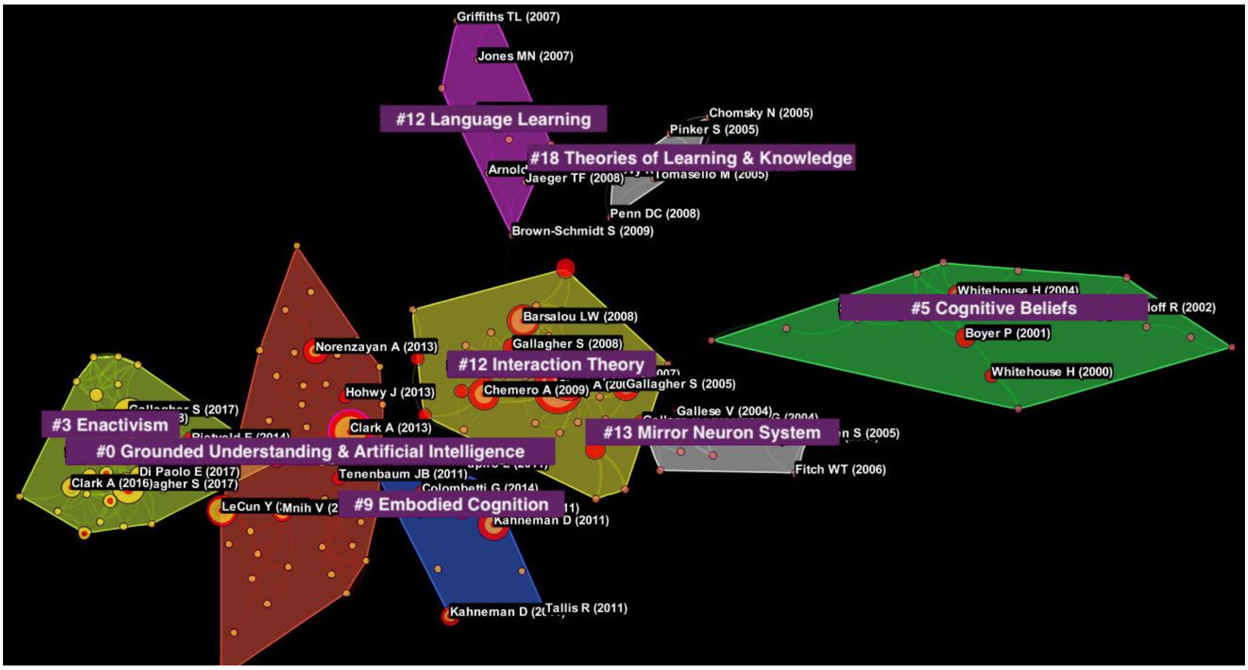

Figure 3. Network of publications generated through the Document Co-Citation Analysis (DCA) on the literature about cognitive science with a focus on the 2000s. The 8 major clusters that were identified are represented by different colors.

Cognitive science from 1977 to 2021

Cluster #23: "Conversation: Computational Linguistics"

In cluster #23 – "Conversation: Computational Linguistics" –, the work by Hobbs and Evans (1980) constituted the major citing document. The document had a coverage of 50, which corresponds to the number of documents in the cluster that were cited by the paper. Hobbs and Evans (1980) applied planning models developed in Artificial Intelligence to understand the planning needed for conducting a conversation. Because of the interest towards the cognitive mechanisms underlying a conversation, many documents included in cluster #23 examined aspects of language and social interactions under a cognitive framework (Cohen, 1978; Linde & Goguen, 1978).

Table 2

Metrics of the 8 major clusters identified when computing the Document Co-Citation Analysis (DCA) on on the literature about cognitive science with a focus on the 2000s.

Cluster ID	Size	Silhouette	Mean Year	Assigned Label
0	42	0.997	2013	Grounded Understanding & Artificial Intelligence
2	36	0.969	2007	Interaction Theory
3	33	0.962	2016	Enactivism
5	18	1.000	2002	Cognitive Beliefs
9	13	0.967	2011	Embodied Cognition
12	10	0.99	2007	Language Learning
13	9	0.978	2005	Mirror Neuron system
18	6	0.989	2006	Theories of Learning & Knowledge

Clusters #4 and #3: Process of Attribution Making

The major citing document in cluster #4 – namely, "Causal Attribution"– was represented by Newcombe and Rutter (1982), with a coverage of 90. In their publication, Newcombe and Rutter (1982) discussed the methodological problems of questionnaire research into Kelley's ANOVA model. In their model, Kelly compared the attribution process (how people process unfolding sequences of behavior) to the statistical procedure of analysis of variance (ANOVA) (Kelley, 1973). Many other cited documents in the cluster explored the dimensions of Kelley's ANOVA model of attribution or the process of attribution making (Zuckerman, 1978; Kelley & Michela, 1980; Pruitt & Insko, 1980). Among other contributions, Nisbett and Wilson (1977) argued that people are often inaccurate on attribution processes applied on themselves because they lack access to their cognitive processes. Moreover, Newcombe and Rutter (1982) posited that some methodologies adopted in cognitive science could represent a remedy to the naive models and methods of attribution researchers and could expand the ability of social psychologist to build models of causal attribution (Smith & Miller, 1979). Thus, many documents in the cluster were cited because they discussed methodologies or pivotal concepts in the cognitive science approach (Abelson, 1981), or even because they applied such concepts to the developing field of Artificial Intelligence (Schmidt, Sridharan, & Goodson, 1978; Pylyshyn, 1980).

In cluster #3 – namely, "Discourse Comprehension" –, two publications were the major citing documents: Rickheit et al. (1985) and Lang (1987). Within the cluster, they had a coverage of

84 and 27 references respectively. In particular, the chapter by Rickheit et al. (1985) introduced and reviewed the concept of inference in discourse comprehension. The chapter also provided a discussion on the distinction between inference and comprehension, some classifications of inference and an examination of some methodological problems included in experimental inference research. Cognitive approaches on text and discourse comprehension were discussed by many cited papers of the cluster (Anderson, Reynolds, Schallert, & Goetz, 1977; Van Dijk, Kintsch, et al., 1983).

Cluster #6: "Language & Mind"

The commentary by Sperber (1983) on the work by Wilensky (1983) was the main citing document in cluster #6, "Language & Mind", and has a coverage of 97 documents. Both works discussed about the contribution of story grammars, where scholars see stories as linguistic forms, to a theory of stories. In their works, authors examined the role of cognitive science in understanding the structure of stories and narratives, and many related publications were cited in the network (Kintsch & Greene, 1978; Black & Wilensky, 1979).

Cluster #17: "Bottom-Up Approach"

In cluster #17, "Bottom-Up Approach", the publication authored by Lloyd (1987) was the major citing document, with a coverage of 47 references.

In their work, Lloyd (1987) proposed a theory, in which mental representations are seen as changed states of a representing device in response to information received over multiple channels (see also Fodor (1983)). An analysis of mental representation and images was included in several cited documents in the clusters (Shepard & Cooper, 1986). In this framework, the neurobiological basis of learning, a process that implies changes in the mental representations, were explored too by the cited references (Kandel & Schwartz, 1982; Kelso, Ganong, & Brown, 1986).

Cluster #26: "Cognisance"

In cluster #26, manually renamed as "Cognisance", the major citing document was authored by Russell (1989). The author focused their work on the concept of cognisance, "a subject's knowledge of his relation to the physical world as an experiencer of it", and outlined a strategy for developing a scientific psychology of cognisance. To guide the definition of the ideal scientific approach on cognisance, many existing methods and developmental theories of knowledge were cited in the cluster (Marshall, 1984; Anderson, 1987; Fodor & Pylyshyn, 1988).

Cluster #51, #5 and #36: Connectionism

The major citing document in cluster #51, which was named "Artificial

Intelligence Engineering", was authored by Franck (1989) and had a coverage of 27 references. The paper by Franck (1989) examined the characteristic of a multiple layer semantic net as a cognitive science framework for representing knowledge at various levels of abstraction. Accordingly, several cited documents dealt with Artificial Intelligence and other technologies to better understand processes of human decision making and cognition (Kuipers, 1986; Winograd & Flores, 1986).

The development of Artificial Intelligence engineering led to the growth of connectionism, which was examined by clusters #5 and #36. Specifically, Carroll (1989) authored the major citing document in cluster #5, renamed "Connectionism", with a coverage of 44 documents. As the authors posited, in cognitive science, mental processes are seen as algorithms computed over knowledge representations. This assumption constitutes the basis for the development of the connectionist approach, in which mental processes are understood through the usage of Artificial Intelligence networks. Many documents in the clusters discussed the potential applications of the connectionist approach in the understanding of the human mind (McCloskey, 1991; Feldman & Ballard, 1982; Fodor & Pylyshyn, 1988; Pinker & Prince, 1988). In cluster #36 - namely, "Connectionism & Education" -, the work by Schneider and Detweiler (1988) was the major citing document, with a coverage of 24 papers. In cluster #36, the connectionist approach is analyzed in relation to educational and learning issues by many cited references (Ohlsson, 1986; Wenger, 1987).

4.2. Cognitive science with a focus on the 2000s

Cluster #5: "Cognitive Beliefs"

Cluster #5, "Cognitive Beliefs", was built around the publication by Tremlin (2010), which was the main citing document with a coverage of 4 documents. Several other documents in the cluster analyzed the cognitive roots of religious beliefs (McCauley & Lawson, et al., 2002; Barrett & Lanman, 2008).

Clusters #13, #2, #9, #0, and #3: Social Cognition

The major citing documents in cluster #13 – "Mirror Neuron System" – were authored by Chaminade (2006), Chaminade and Hodgins (2006), Sommerville and Decety (2006) and covered 3 documents each. The main three citing documents, as others in the cluster (Losin, Dapretto, & Iacoboni, 2009), stem from the discovery of the mirror-neuron system, the neural substrate in which observed and executed actions are commonly coded, and that it is believed to be the basis of the understanding of others' actions (Rizzolatti, Fogassi, & Gallese, 2001; Rizzolatti & Craighero, 2004).

Froese (2009) and Froese and Gallagher (2012) authored the two major citing documents in cluster #2 - renamed as "Interaction Theory" - with a coverage 6 documents each. In the two major citing documents of the cluster, the authors argued that "theory theory" (based on belief-desire inferences) and "simulation theory" (based on the mirror-neuron system) accounts have traditionally dominated the debate concerning the understanding of social cognition. Alternatively, Froese and Gallagher (Froese & Gallagher, 2012b) argued that embodied social interactions are the foundations of human social cognition and they precede the personal-level capacity for detached social cognition. Accordingly, both enactive and interaction theory (IT) approaches, which stem from developmental, phenomenological, enactive, and dynamical evidence, show that social understanding abilities rely on human interactions and social contexts. Thus, the cluster includes several citing and cited papers which examined the "theory theory", "simulation theory", enactive and IT accounts on social cognition (Gallagher, 2006; Barsalou, 2008; Chemero, 2011).

Other two perspectives (i.e., enactivism and grounded cognition) in the debate regarding the understanding of social cognition were examined in clusters #9, #0, and #3. In cluster #9, "Embodied Cognition", the major citing document was authored by V¨or¨os et al. (2016) with a coverage of 4 documents and the embodied cognition perspective was examined by other documents in the cluster (Shapiro, 2011; Galen, 2017).

Cluster #0, which was renamed "Grounded Understanding & Artificial Intelligence", had the publications authored by Galen (2017), Hayes and Kraemer (2017) and Lake et al. (2017) as major citing documents, all of them having a coverage of 4 documents. In agreement with the title, documents in the cluster referred to the grounded understanding approach, with insights on Artificial Intelligence (Tenenbaum, Kemp, Griffiths, & Goodman, 2011; Glenberg & Gallese, 2012).

In cluster #3 - namely, "Enactivism" -, the major citing documents were authored by Nave et al. (2020) and Ramstead et al. , both with a coverage of 6 documents. In particular, Ramstead et al. (2021) proposed a multiscale integrationist interpretation of the boundaries of cognitive systems, where they argued the possible coexistence of internalist (e.g., enactive and embodied cognition) and externalist views of cognition. Accordingly, the cluster was shaped by many citing and cited documents on the enactive perspective (Hutto & Myin, 2013; Gallagher, 2017).

Cluster #18 and #12: Minimalism & Language Acquisition

The theme of language emerged in two clusters of the network: clusters #18 and #12. In cluster #18, "Theories of Learning & Knowledge", the two major citing documents were authored by Golumbia (2010) and Plotkin et al. (2007), each of which covered 3 documents. These articles, as well as the other citing documents (Botha & Knight, 2009; Chater & Christiansen, 2010), dealt specifically with theories of learning and knowledge, particularly words, language, and symbolic learning. In terms of cited documents, learning and language were almost always taken into account under an evolutionary framework (Chomsky, 2005; Pinker & Jackendoff, 2005). Many of the listed documents examined the evolution of language and the distinction between human and non-human cognition.

Language was also discussed in cluster #12, "Language Learning". In this cluster, the first three citing documents were authored by Kintsch and Mangalath (2011), Matthews et al. (2012) and Riordan and Jones (2011) and all had a coverage of 3 documents. Documents in the cluster examined language learning (e.g., syntax and grammar) under a psycholinguistic approach in the cognitive science theoretical frame (Jones, Kintsch, & Mewhort, 2006; Van Deemter, Gatt, Van Gompel, & Krahmer, 2012)

General Discussion

Multidisciplinary nature of the cognitive science literature

When analyzing the main clusters, a multidisciplinary theme clearly emerges in the literature on cognitive science. Contributions from various fields, such as psychology, linguistics, neuroscience, computer science, anthropology, and philosophy, dynamically interacted to shape the cognitive science literature over the years. Combined approaches of disciplines also gave rise to new fields of research. These new fields of research include computational linguistics (combination of linguistics and computer science), cybernetics (combination of computer science and neuroscience), psycholinguistics (combination of psychology and linguistics), and more. Not only does the general multidisciplinary approach found in the current review agree with the original cognitive science manifesto (Keyser, Miller, & Walker, 1978), but so does the role played by each discipline in the cognitive science framework. In fact, Miller (2003) theorized that psychology, linguistics, and computer science were meant to be central in cognitive science, whereas other disciplines would have been more peripheral. This centrality/periphery hierarchy in cognitive science also emerges from the discussion of the main clusters in the networks, where themes and methods from psychology, linguistics, and computer science are more recurrent than themes from neuroscience, anthropology, and philosophy.

Temporal shift in the cognitive science literature

In the current work, two DCAs were computed on two data samples. The DCA computed on the first data sample - from 1977 to 2021 – generated nine major clusters with a strong emphasis on language, cognitive theories, and cognitive models. Conversely, the DCA computed on the second data sample - on the 2000s - included eight major clusters with a stronger emphasis on more physiologically-based approaches (e.g., embodied cognition, mirror neuron system). The differences in the research emphasis between the two DCAs are of particular interest and may reflect scientific and technological changes in the study of cognitive systems throughout the years. In fact, the initial strong focus of the cognitive science community towards the study of language in a cognitive perspective might represent a response to the difficulties faced by behaviorist theories when trying to explain language in terms of reinforced learning. Conversely, the shift from an interest towards cognitive theories and models to more physiologically-based approaches to cognitive systems in the 2000s may stem from the technological advances in the study of human physiology and brain activity in vivo. Within the last decades, there has been an increased adoption of such methods in cognitive science research, shifting from the molecular level of analysis to more systemic approaches. This in turn led to the simultaneous study of multiple individuals in social contexts (i.e., second person neuroscience approach) in the latest years (Azhari et al., 2019). Such trends in the research methods in cognitive science finds agreement in the available literature (Yeung et al., 2017), Altimus et al., 2020).

Conclusions

The current study adopted a scientometric approach on data regarding the literature on cognitive science in toto and with a focus on the 2000s. The DCAs computed with CiteSpace gave insights regarding both the most impactful publications in the cognitive science field and the thematic domains of research that gave shape to the scientific literature on the topic. When analyzing the content of the thematic clusters in the network, the interdisciplinary which characterize cognitive science strongly transpired, thanks to the interaction between psychology, linguistics, neuroscience, computer science, anthropology, and philosophy.

The interpretation of the results from the current scientometric paper require consideration of some limitations that are intrinsic to the methodology (Carollo et al., 2021b; Carollo et al., 2021c; Lim et al., 2021). First of all, the results of this paper strongly depend on the selected keywords that drove the research on Scopus. Some relevant papers in the field of cognitive science may have not been included in the data pool because they were not captured by the string "TITLE-ABS-KEY ("cognitive science") AND (LIMIT-TO (LANGUAGE,"English"))". Also, the platform used to download the data sample - in this case Scopus - may have an impact on the results. Further studies may extend the insights from this paper by using other scientific databases, such as Web of Science. Finally, the analysis of co-citation patterns underlying the current paper implies two further limitations. Specifically, by examining the pattern of co-citation on a quantitative fashion, no insight is provided in regard to the nature of the co-citation. Also, the analysis of co-citation patterns rarely allows the most recent documents to be included in the list of most impactful publications in the field of interest. In other words, when relying on citation patterns between documents there is always a bias towards past publications. Therefore, more recent documents may not be included not because they are less important or impactful, but because they have had less time to obtain citations.

Even when considering the aforementioned limitations, the current paper provided a systematic insight into the literature about cognitive science, unveiling and highlighting once again the interdisciplinary of the examined paradigm.

Authors' contributions

All authors contributed equally to the development of the research concept, the design of the study, the analysis and interpretation of data, and the preparation and editing of the manuscript. The authors jointly participated in the selection and systematization of scientific sources, discussion of the results obtained, and formulation of conclusions. All authors reviewed the final version of the article and approved it for publication.

Conflicts of interest

The authors declare no conflict of interest.

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«Когнитивтік (р)эволюция». Когнитивтік ғылым парадигмасындағы үрдістер мен даму бағыттарын шолуға арналған ғылымиметрикалық көзқарас

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Андатпа. Когнитивтік ғылым когнитивтік жүйелерді зерттеу үшін пәнаралық тәсілді қолданады. Когнитивтік ғылым бойынша әдебиеттерге жүйелі шолу жүргізу мақсатында Scopus дерекқорынан екі деректер жиынтығы жүктелді: біріншісі когнитивтік ғылымға қатысты барлық әдебиеттерді қамтыды (N = 13 414 құжат), ал екіншісі 2000-жылдардағы жарияланымдарды қамтыды (N = 12 337 құжат). Әрбір деректер жиынтығы үшін CiteSpace бағдарламасының көмегімен құжаттардың бірлескен дәйексөзделуін талдау (Document Co-citation Analysis, DCA) жүргізілді. Кластерлерді талқылау нәтижесінде пәнаралық тәсілдің айқын көрінісі байқалады. Психология, лингвистика, нейробиология, информатика, антропология және философия салалары көптеген жылдар бойы когнитивтік ғылым әдебиетінің қалыптасуына үлес қосты. Атап айтқанда, 1977–2021 жылдар аралығындағы іріктемеде анықталған кластерлер когнитивтік теориялар мен модельдерге басым назар аударылғанын көрсетті. Ал 2000-жылдардағы әдебиеттерде анықталған кластерлер физиологиялық бағытқа көбірек көңіл бөлген. Жүргізілген талдау когнитивтік ғылымның екі маңызды аспектісін айқындайды: (i) осы саланың пәнаралық сипаты; (ii) технологиялық жетістіктердің бұл саланы физиологиялық тұрғыдан бағдарланған бағытқа қайта бағдарлауы.

Түйін сөздер: когнитивтік ғылым, құжаттардың бірлескен дәйексөзделуін талдау, ғылымиметрия, пәнаралық зерттеулер, библиометриканың шектеулері, дәйексөз берудегі бейтарапсыздық, дерекқорларға тәуелділік.

«Когнитивная (р)эволюция». Наукометрический подход к обзору тенденций и направлений развития в парадигме когнитивной науки

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Аннотация. Когнитивная наука использует междисциплинарный подход для изучения когнитивных систем. Для систематического обзора литературы по когнитивной науке из Scopus были загружены две выборки данных: одна касалась всей литературы по когнитивной науке (N = 13 414 документов), а другая включала литературу 2000-х годов (N = 12 337 документов). Для каждой выборки был проведен анализ совместных цитирований документов (DCA) с помощью CiteSpace. Из обсуждения кластеров вырисовывается междисциплинарный подход. Психология, лингвистика, нейробиология, информатика, антропология и философия сформировали литературу по когнитивной науке на протяжении многих лет. В частности, кластеры, выявленные в выборке с 1977 по 2021 год, показали сильный акцент на когнитивных теориях и моделях. Напротив, кластеры, выявленные в литературе 2000-х годов, уделяли больше внимания физиологическому подходу. Наш анализ выделяет два важных аспекта в когнитивной науке: (i) междисциплинарный характер этой области; и (ii) то, как технологические достижения переориентировали эту область в сторону более физиологически ориентированного подхода.

Ключевые слова: когнитивная наука, анализ совместных цитирований документов, наукометрия, междисциплинарные исследования, ограничения библиометрики, предвзятость цитирования, зависимость от баз данных.

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