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Dual-task and movement: a bibliometric study based on high-impact search engines
Doble tarea y movimiento: estudio bibliométrico basado en motores búsqueda de alto impacto

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Abstract. The interest and impact of scientific productions on dual-task and movement in recent years have demonstrated the worldwide relevance of this topic, especially in neuroscience, neurorehabilitation, and cognitive stimulation. Therefore, this research aims to conduct a bibliometric study on the scientific production published on dual-task and movement in high-impact search engines in the last decade, from 2012 to 2022. Once classified and parceled out all the information, screening was carried out, obtaining a final sample of 175 articles. The main findings that emerge from the research reviewed highlight the great benefits that dual-tasking and movement have on humans, especially in older age. Despite this, it should be noted that recent studies focus on younger participants, most of whom are of school age. Hence, considering that this practice has been proven to be highly effective, it would be convenient to implement it in the educational field in order to determine whether it can improve the integral development of the human beings.
Keywords: dual-task, movement, executive functions, Bapne, cognitive stimulation.

Resumen. El interés e impacto en las producciones científicas sobre la doble tarea y el movimiento en los últimos años han evidenciado la relevancia a nivel mundial de esta temática, especialmente en el campo de la neurociencia, la neurorrehabilitación y la estimulación cognitiva. Por ello, el objetivo de esta investigación es realizar un estudio bibliométrico sobre la producción científica publicada en torno a la doble tarea y el movimiento en motores de búsqueda de alto impacto en la última década, esto es, desde el año 2012 hasta el año 2022. Una vez clasificada y parcelada toda la información, se ha realizado un cribado, obteniendo una muestra final de 175 artículos. Los principales hallazgos que se desprenden de las investigaciones analizadas destacan los grandes beneficios que la doble tarea junto con el movimiento tiene en los seres humanos, especialmente en edad avanzada. A pesar de esto, cabe destacar que los estudios recientes se centran en participantes mucho más jóvenes, estando la mayoría de estos en edad escolar. Por tanto, si se conoce que esta práctica es tan altamente efectiva, sería conveniente aplicarla dentro del ámbito educativo para comprobar si realmente puede llegar a mejorar el desarrollo integral de los seres humanos.
Palabras clave: dual-task, movimiento, funciones ejecutivas, Bapne, estimulación cognitiva.

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Introduction

In recent years, scientific production related to dual-task has increased considerably in the medical field and, especially, in the field of rehabilitation and cognitive stimulation. The term dual-task can be defined as the ability to simultaneously perform several activities or tasks. However, this definition has given rise to multiple debates and misunderstandings over the years, especially about the interference of dual-task on cognitive resources. That is, concerning how cognitive resources such as attention or cognitive processing are distributed when performing several tasks simultaneously.

Movement and motor coordination have numerous studies that demonstrate their benefits in humans not only at the physiological but also at the neurological level (Martínez-Heredia et al., 2021; Romero-Naranjo & Sayago-Martínez 2021a). From an educational perspective, movement has a unique importance in motor learning (Burbano-Pantoja et al., 2021; Pérez-Hernandéz et al., 2022), as well as in language (Pacheco-Delgado et al., 2022; Padial-Ruz et al., 2022; Zambrano-Pintado et al., 2022), and at the cognitive (Mezcua-Hidalgo et al, 2020), social (Aguilar-Herrero et al., 2021) and emotional levels (Álvarez-Ibáñez & Fernández-Hawrylak, 2022; Luisde Cos et al., 2019). Likewise, it is important to highlight all its benefits regarding cases of Developmental Coordination Disorders and Attention Deficit Hyperactivity Disorder (ADHD) (Palma-Marifil, 2021; Villa de Gregorio et al., 2019).

The purpose of this research is to conduct a bibliometric study on Web of Science on this topic, since, to date, no study of these characteristics has been carried out on dual-task and movement in primary bibliographic search engines. Due to the large number of publications, it is important to parcel out all the information collected in the last ten years (2012-2022) in order to detail which are the most relevant theories and studies.

Early contributions

Posner & Snyder (1975) proposed an attentional model that distinguished between automatic and controlled processing when performing a task. They used the dual-task paradigm to investigate the distribution of the attentional processes between the two different tasks that are performed simultaneously. Years later, Shallice (1988), while investigating cognitive processing in patients with brain lesions, designed a model of cognitive control based on the idea that the brain has independent systems which control different types of cognitive processing. He claims that the performance of a secondary task can interfere with the cognitive control necessary to perform a primary task. In this sense, Pashler (1994) takes up the idea of interference between the two tasks affirming in later studies that the central attentional system has a limited number of resources and, in the case of not having sufficient resources

when performing different tasks, it can produce deficits in one or both activities (Meyer & Kieras, 1997; Pashler et al., 2001). This is called dual-task interference or dual-task costs (DTC) (Kinsbourne & Hicks, 1978).

Despite this and as highlighted by Tirapu et al. (2015) in their study, the "functional fields" hypothesis suggests that it is not possible to perform two tasks that share the same functional field simultaneously (Roland, 1993) since it is limited and interference may be due to limitations in information processing capacity (Tombu & Jolicoeur, 2003). In this sense, Miyake & Shah (1999) argue that the working memory consists of multiple components, including the ability to maintain and actualize information and to control and coordinate cognitive processes.

Furthermore, some studies discuss that dual tasks do not compete for attentional resources, but collaborate with each other. Schumacher & D'Emposito (2002) state that when two tasks share the same cognitive process, the dual-task can improve the performance of both. In this regard, Szameitat et al. (2011) add that dual-tasking improves performance on both tasks when the secondary task does not require many cognitive resources in order to be performed, while Strobach et al. (2012) claim that, in some situations, dual-tasking can actually improve performance compared to single-task work. In addition, more recent studies like those of Nudo (2013) and Maier et al. (2019) indicate that the brain is not composed of competing systems, but rather forms a global and general system responsible for managing and executing in the best possible way and at any given time the limited cognitive resources.

Despite these findings, it should be noted that most studies are still inconclusive, given that many more argue that dual-tasking tends to interfere with cognitive performance due to the limited resources humans possess to process information.

Terminological differences

The interest in scientific production on neuroscience and neurorehabilitation has led to the creation and popularization of various terms which, in some studies, have generated confusion with the term dual-task due to the imprecision in their meaning.

The term multitasking began to be used to refer to computer processing (Rosen, 2008) and in recent years has been incorporated into the field of neuroscience referring to the action of performing several activities at the same time (Ophir et al., 2009). The difference between multitasking and dual-tasking is that multitasking is the general paradigm within which dual-tasking is more specifically embedded since multitasking does not specify that the performance of different tasks has the same relevance and, therefore, the performance and quality do not necessarily have to be optimal in all the tasks performed. For this reason, studies like Madore & Wagner (2019) indicate that the term multitasking is inappropriately used as a justification for the fact that human beings are constantly carrying out different tasks simultaneously on a daily basis since the attentional and cognitive resource overload necessary would be very high. This would cause task performance to be very low, especially if the performance of different tasks at the same time lasts for a long period of time. Likewise, other authors point out that it is not possible to perform several activities simultaneously, but instead, there are changes in cognitive resources in terms of focusing on one task or another (Burgess et al., 2000; Pashler, 2000). This is known as task-switching.

Task-switching is also a term commonly confused with dual-task, especially by authors who support, as specified above, that it is not possible to perform two or more tasks at the same time. In this sense, task-switching is also identified as a paradigm within multitasking as well as dual-tasking, but they are not synonyms. According to Monsell (2003), task-switching can be defined as a multitasking situation where two or more tasks are processed sequentially, that is, without temporal overlap. In addition, Worringer et al. (2019) state that when dual and task-switching tasks are performed, they share attentional switching, motor intentions, and effort regulation, but in turn, they differ in that brain activation is significantly higher during the dual task.

Divided attention is not a synonym either since it is the cognitive function that allows a response to different stimuli simultaneously (Kahneman, 1973; Navon & Gopher, 1985). Therefore, divided attention is necessary to perform a dual task because it is responsible for distributing attentional resources in order to be able to perform a complex task or several tasks at the same time (Añaños, 1999).

Finally, another term that has become popular recently in neuroscience is branching. This term, like dual-task, is an additional component of the executive functions (Koechlin et al., 1999; Koechlin et al., 2000) that successively distributes the processing resources of synchronous tasks. The main difference is that in branching the goal is not to perform the tasks at the same time but rather to organize and optimally perform the tasks simultaneously, interspersing them and taking into account where are each one in the task, returning to the initial task at the end of the other secondary tasks (Koechlin et al., 1999).

In summary, despite the lack of a specific definition accepted by all authors, dual-tasking is defined as the ability to perform two tasks independently, measured separately and with different objectives, but performed simultaneously (McIsaac et al., 2015). However, this term, up until now, seems to have no synonyms.

Theoretical models

Due to the discrepancies generated regarding this topic, three theoretical models have been developed that reflect the ways in which researchers have defended, through their research findings, how cognitive interference occurs (Kalron et al., 2010).

The first model is the theory of capacity or resource sharing which states that the resources that human beings possess are limited. Therefore, when several tasks are

performed simultaneously, the interferences generated between them may affect the correct performance of one or all of the activities performed if the processing capacity is not able to correctly manage the information received. The second one, the cross-communication or crosstalk theory model, also known as the compensation model, argues that if both tasks are performed simultaneously and use the same neural networks the interference is minor.

Finally, the third model corresponds to the bottleneck or adaptive complexity theory, which expounds that the performance of two tasks with the same neural processing pathway may compete for cognitive resources causing interference between them (Tombu & Jolicoeur, 2003) or, on the contrary, interference will not occur if tasks do not share the same resources (Pashler, 1994).

Once the different theoretical models have been described and defined, it is important to highlight the contribution of Bayot et al. (2018). They provided another classification in order to delimit the definition of dual-task based on how the human brain processes information and how cognitive resources are distributed when performing two tasks.

In the first place, the so-called Capacity sharing theories stand out. They argue that the performance of dual tasks is limited to the capacity of the cognitive resources available. These theories are divided into two subcategories: central capacity-sharing models and multiple resource models. The first claims that there is a central resource or parallel processor of limited capacity that all tasks share, meaning that task performance depends on the order that this central resource receives. The second explains that there are various cognitive resources and each task has assigned a different one. Therefore, task performance depends on the amount of resources assigned.

In the second place, the theory or model called Crosstalk corresponds to the crosstalk model described above. This theory holds that the performance of each task will depend on the extent to which both tasks share cognitive resources. In this case, the authors discuss the fact that, if the two tasks use the same resources or are of similar domains, there will be no interference since performing these types of tasks that are similar in terms of the use of neural resources could increase the efficiency of information processing by not requiring considerable attentional resources.

In contrast, the theory proposed by Nijboer et al. (2014), the Time-sharing hypothesis, defends that two tasks are not performed completely simultaneously but distributed in time instead. For that reason, tasks alternate between them, activating the brain areas underlying each one to a lesser extent in a dual-task situation than in a single-task situation, as they are accessed less frequently.

Finally, the Bottleneck theory is presented, which determines the model previously introduced by Kalron et al. (2010) since, in this case, it aims to explain the deterioration in performing dual tasks as a result of the serial processing required when both tasks need the same neural network to manage them or when several neural networks overlap. This theory includes two subcategories: structural bottleneck theories and strategic bottleneck theories. In the first one, the so-called "bottleneck" happens due to structural limitations in cognitive processing, such as working memory. In the second one, the "bottleneck" is due to a strategic limitation in cognitive processing, such as the limited capacity for the coordination of cognitive processes and resources.

It is also worth noting that there are discrepancies in deciding whether dual-task work has beneficial effects or whether, on the contrary, the interference it causes may be detrimental. Studies by Al-Yahya et al. (2011) expose that working dual-task in cognitive-motor exercises through gait training with older people may have a higher cognitive and motor price and contribute to an increased risk of falls. Strobach & Schubert (2017), on the other hand, defend that the costs of dual-tasking at the beginning may appear. However, they can be reduced if done repeatedly and constantly since practice can also improve the ability to perform multiple tasks simultaneously.

Dual-task paradigms

Dual-task work depends on the type of tasks or activities performed, so it is important to highlight the different paradigms established over the years according to the findings of dual-task research.

Cognitive-cognitive paradigm

The cognitive-cognitive paradigm refers to different models of dual-task performance involving one task with a cognitive component and another task in which cognitive processes are also involved. Some relevant studies on this paradigm are, among others, those of Baddeley & Hitch (1974); Corlu et al. (2015); Insaridze & Bzhalava (2010); Karatekin (2004); Wang & Gathercole (2013).

Cognitive-motor paradigm

The cognitive-motor paradigm is one of those that has aroused the most interest among the authors since it is the one with the most scientific publications. In this case, a task with a cognitive component and another with a motor component are involved. This paradigm compares and contrasts the results of the dual-task with the motor performance, on the one hand, and the performance of the cognitive task, on the other, i.e., they analyze the results separately and as "single or simple" tasks. Several relevant articles are found in this paradigm, among which the following authors stand out: Bridenbaugh & Kressig (2015); Crockett et al. (2017); Falbo et al. (2016); Fino (2016); Fok et al. (2011); Haggard et al. (2000); Hawkins et al. (2018); Lin & Lin (2016); Lundin-Olsoon et al. (1997).

Motor-motor paradigm

The motor-motor paradigm refers to different models of dual execution in which two tasks with a motor component are involved. This paradigm has generally been used for the

rehabilitation of patients with cardiovascular accidents. Some of the most influential authors in this paradigm and their respective studies are Amboni et al. (2012); Beurskens & Bock (2013); Hung et al. (2013); Hung et al. (2013); Lee et al. (2017); Shim et al. (2016); Yang et al. (2007).

Rhythmic-motor paradigm

In the rhythmic-motor paradigm, a rhythmic task and a task with a motor component are performed simultaneously. This paradigm was acknowledged thanks to the studies of Kim et al. (2017a, 2017b) and Kim & Yoo (2020), who demonstrated through electroencephalography (EEG) recordings its benefits. Despite this, there are earlier studies that already advocated the use and benefits of employing these types of activities together. Among others, the article of Park et al. (2014) stand out, and the collaboration in several subsequent publications with the Korean author (Park & Kim, 2021; Kim et al.,2022).

Cognitive-rhythmic-motor paradigm

Finally, it is also important to note that studies on a possible fifth paradigm called cognitive-rhythm-motor are currently beginning to be published. The BAPNE method uses this new paradigm. However, it has not yet been possible to demonstrate the benefits that this mix of tasks could have on the human brain. Some of these emerging studies (Alonso-Marco & Romero-Naranjo, 2022; Álvarez-Morales & Romero-Naranjo, 2019; Andreu-Cabrera & Romero-Naranjo, 2021; Arnau-Mollá & Romero-Naranjo, 2022a, 2022b; Di Russo & Romero-Naranjo, 2023; Romero-Naranjo, 2013a, 2013b; 2016, 2020, 2022; Romero-Naranjo & Sayago-Martínez, 2021; Romero-Naranjo & Andreu-Cabrera & Arnau-Mollá, 2023; Romero-Naranjo & Pujalte-Cantó & Arnau-Mollá, 2023; Romero-Naranjo & Llorca-Garnero, 2023; Romero-Naranjo & Andreu-Cabrera, 2023a, 2023b, 2023c, 2023d).

The interest in dual tasks and the exponential growth in scientific publications on this subject, especially those related to tasks involving movement, underline the relevance of this term in neuroscience and neurorehabilitation. This fact, together with the debates among the authors and the lack of bibliometric studies exposing the current situation on dual-task, have been the main incentives to carry out the present study. Therefore, the present research aims to carry out a bibliometric study of the scientific production published on dual-task and movement in high-impact search engines in the last 10 years, from 2012 to 2022.

Method

This section describes the process of selecting the sample of articles that have been analyzed in this study and presents the findings.

Sample

This bibliometric review was carried out using an ex post facto retrospective design (Montero and León, 2005), which is why the procedure used, as described in more detail in the following sections, was based on the search and selection of the documents followed by their classification according to the descriptors of the articles and the analysis of the data they provide (Rosa et al., 1996). In this case, 175 empirical articles were selected from the 1805 documents (806 articles) published between January 1st, 2012, and December 31st, 2022, in the Web of Science (WOS) database.

Tools

Web of Science is a primary online search engine integrated into the Institut of Scientific Information (ISF) Web of Knowledge, a platform that includes multidimensional databases that enable data searches in journal articles, evaluation tools, conference proceedings, patents, and analysis of published information such as impact factor, immediacy index, bibliographic management resources, and Web resources. The articles published in journals indexed in this search engine have been used for this study. Because the term dual-task is broad and can be classified into several categories, the searches offered by WOS in all the databases and all the categories have been used in an attempt to access the largest possible sample of documents on the subject.

Procedure and analysis

For the selection of the sample, a search of the units of analysis was carried out, that is, the keywords or those considered to be of interest and related to the main theme to be analyzed, such as dual-task and movement. The main terms and those related were combined to design the search strategy using Boolean operators, both for expansion and restriction, in an attempt to narrow down the results obtained by the search engines as much as possible.

In the course of the creation of the search strategy, terms that are either synonyms or related to the two main terms were collected. Once a list of all the selected words was made, they were combined with the Boolean operators. The ones that provided more results were added and, on the contrary, the ones that did not provide new documents were eliminated. Thus, for this article, and after several tests and combinations, the following search strategy was used: ("dual task*") and ("move*" or "motor activity" or "motor skills" or "motor ability" or "music" or "dance" or "rhythm" or "psychomotor activity"). The result, filtered by year, from 2012 to 2022, was a total of 1805 documents. In addition, to narrow it down, the results were also filtered by type of document, excluding the ones that were not articles. It resulted in a final output of 806 documents.

In order to establish a final sample of articles that met the research objectives, inclusion and exclusion criteria were established to facilitate the decision on whether to eliminate or accept the documents obtained. The inclusion criteria were: I) the articles had to be empirical; II) had to

be published between 2012 and 2022; III) and fit the subject matter under analysis.

As for the exclusion criteria, the following stand out: I) that activities in which there was motor content were used; II) that the movement involved displacement, i.e., not static motor activities (eye movements, rotation/flexion of the limbs, postural control, facial movements, etc.); III) that dual-task would be identified with the words mentioned in the previous section, which are not synonymous (multitasking, task-switching, branching, divided attention); IV) that, although the term dual-task is specified, no activities adjusted to the paradigms shown in previous sections and involving displacement (motor-motor, cognitive-motor, rhythmic-motor, cognitive-rhythmic-motor) were performed; V) theoretical works such as systematic reviews or meta-analyses.

Once set the exclusion and inclusion criteria, we proceeded to read the articles previously obtained in WOS (n=806). In the first instance, from the titles and abstracts, a total of 606 articles were discarded. The main reason was that although one of the activities involved a motor component, it did not involve movement. Then, of the remaining 200 articles, a more detailed reading was done to ensure that the subject matter was in line with and met the previously established inclusion and exclusion criteria.

After this reading, 25 documents were eliminated, resulting in a final sample of 175 articles.

It is important to note that the sample selection process was complex, mainly due to the medical interest of the double-task. It implied an in-depth reading of most of the articles or, at least, of the methodology used. In many cases, the abstract specified a paradigm involving a motor task. However, it had to be verified that this motor activity involved a displacement of the participants. Likewise, the reading had to be contrasted in many cases, since most of the studies were designed by authors specialized in the field of medicine, especially in neuroscience or neurorehabilitation. For this reason, since the measurement and data collection instruments and the terms used in various studies were very specialized or technical, several information searches were needed in order to understand the findings presented in the studies analyzed.

In order to carry out the analysis of the selected articles, different databases were created using Microsoft Excel, in which the data corresponding to the following categories were organized: temporal variables, including all aspects relevant to the year of publication of the articles; demographic variables, related to the countries of publication and the journals; methodological variables, referring to the research sample, the paradigm and the instrument used in each study, as well as the authors, including their productivity and collaborations; the quality and impact of the publications, that is, the relationship of authors and the number of citations received and, therefore, the impact of the study.

Results

As mentioned in previous sections, the scientific production on dual-task and movement has increased in recent years. From 2012 to 2022, a sample of 175 articles on this subject has been obtained, being the average rate of publications per year 17.5 articles. As shown in Figure 1, the years with the highest productivity were 2019, 2020 and 2022 with more than 25 articles each. These three years represent a 47.71% of the total production, including the publications of the last year, 2022, accounting for 16.57% of the total number of articles analyzed. As can be seen in the figure, this subject had a notable increase of the number of publications starting in 2016 and continuing in the following years up to the present, except for 2018, when the number of articles published decreased (Figure 1).

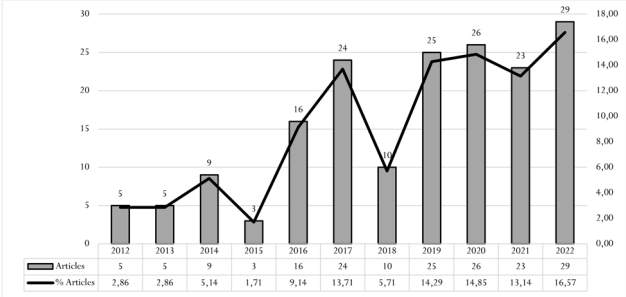

Figure 1. Articles published by year *Note:* Source: WOS; Figure of own elaboration.

Most of these articles (97.14%) were published in English, although, as shown in Table 1, there are also articles in other languages, such as Portuguese (2.29%) or Korean (1.71%), among others (Table 1).

Table 1.
Articles by language of publication

Language	Articles	% Articles
English	170	97.14
Portuguese	4	2.29
Korean	3	1.71
Spanish	1	0.57
Persian	1	0.57
German	1	0.57

Note: Source: WOS; Table of own elaboration.

Despite this, the countries where the articles under analysis have been published are many, as shown in Table 2 and in its visual representation in Figure 2. Switzerland is the country that has published the most articles on dual-task and movement, with 39 of the 175 total articles analyzed (22.29%), followed by the United States with 20% of the publications and the United Kingdom with 16% (Figure 2) (Table 2).

Table 2.
Articles by country of publication

Country	Articles	% Articles
Switzerland	39	22.29
USA	35	20.00
United Kingdom	28	16.00
Ireland	15	8.57
Germany	13	7.43
Netherlands	9	5.14
France	7	4.00
Italy	5	2.86
Brazil	5	2.86
South Korea	3	1.71

8 Asian countries with less than 3 publications	10	5.71
3 European countries with less than 3 publications	3	1.71
1 country in the Americas with less than 3 publications	1	0.57
1 country in Oceania with less than 3 publications	1	0.57
1 country in Africa with less than 3 publications	1	0.57
Total	175	100.00

Note: Source: WOS; Table of own elaboration.

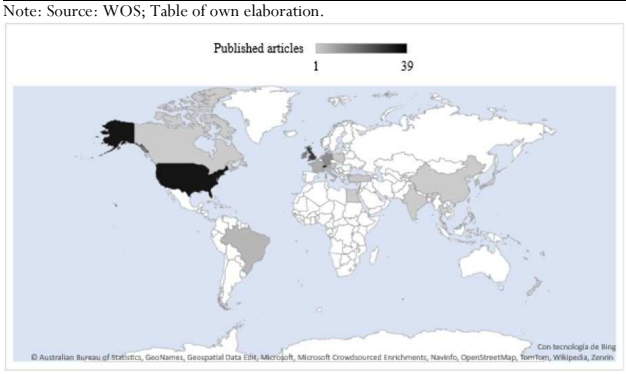

Figure 2. Choropleth map of the countries where the articles are published. Note: Source: WOS; Table of own elaboration.

Furthermore, a total of 101 journals are registered. The journal that collects the highest number of publications is Gait & Posture with a total of 14 articles (8%). It stands out that most of the publications (43.43%) belong to a different journal each. As shown in Table 3, most of the journals are from the medical field and are specialized, in most cases, in neuroscience and neurorehabilitation (Table 3).

Table 3.
Articles according to the journal in which they have been published

Journal	Articles	% Articles
Gait & posture	14	8.00
Experimental brain research	8	4.57
Frontiers in aging neuroscience	8	4.57
Frontiers in neurology	7	4.00
Human movement science	6	3.43
Sensors	6	3.43
Journal of biomechanics	5	2.86
Frontiers in human neuroscience	4	2.29
Frontiers in psychology	3	1.71
Biomedical signal processing and control	3	1.71
Neuroscience	3	1.71
Clinical journal of sport medicine	3	1.71
Brain sciences	3	1.71
Aging clinical and experimental research	3	1.71
Behavioural brain research	3	1.71
10 journals with 2 publications	20	11.43
76 journals with 1 publication	76	43.43
Total	175	100.00

Note: Source: WOS; Table of own elaboration.

Table 4.
Journals with more than three publications

Journals with more than three publications	Articles	% TS	Quartile	Country
Gait & posture	14	8.00	Q2	Ireland
Experimental brain research	8	4.57	Q4	Germany
Frontiers in aging neuroscience	8	4.57	Q2	Switzerland
Frontiers in neurology	7	4.00	Q2	Switzerland
Human movement science	6	3.43	Q4	France
Sensors	6	3.43	Q2	Switzerland
Journal of biomechanics	5	2.86	Q3	UK
Frontiers in human neuroscience	4	2.29	Q3	Switzerland
Frontiers in psychology	3	1.71	Q2	Switzerland
Biomedical signal processing and control	3	1.71	Q2	UK
Neuroscience	3	1.71	Q3	UK
Clinical journal of sport medicine	3	1.71	Q1	USA
Brain sciences	3	1.71	Q1	UK
Aging clinical and experimental research	3	1.71	Q2	Italy
Behavioural brain research	3	1.71	Q2	Netherlands

Note: %TS= Percentage of total sample of articles (n=175); UK= United Kigdom; Source: WOS; Table of own elaboration.

Relating this variable to the previous one, as shown in Table 4, despite Switzerland being the country with the most articles published, the journal with the most publications, Gait & Posture, is an Irish journal of quartile 2 (Q2). However, if the contributions of the Swiss journals with more than 3 publications were added, a total of 28 articles (16%) would be obtained, surpassing the total of Gait & Posture. Furthermore, as shown in the table, only two of the journals with more than three publications belong to quartile 1 (Q1). These are the Clinical journal of sport medicine and Brain sciences, with three publications each, i.e., 1.71% of the total sample of articles (n=175) (Table 4) (Figure 3).

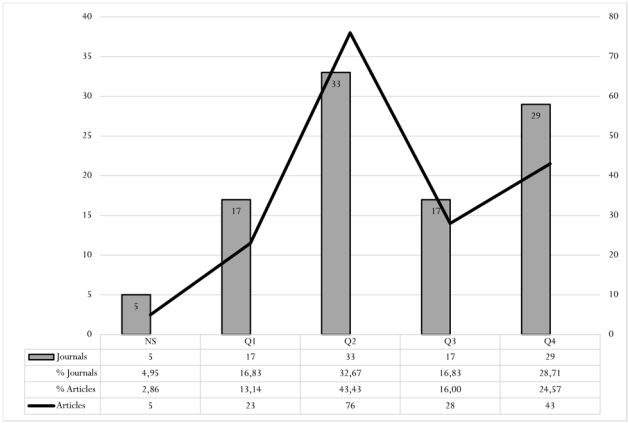

Figure 3. Quartiles of the magazines analyzed. Note: NS=Not specified; Source: WOS; Figure of own elaboration.

With regard to quartiles, which is the measure that determines the order of the journals according to their impact factor, the predominant one in the articles selected for analysis is Q2, with 32.67% of the published articles, followed by Q4 with 43 articles, and quartiles 1 and 3 with 16.83% as shown in Figure 3.

The productivity of the authors (n=851) is presented according to the number of articles published, as shown in Table 5. David R. Howell (4%), William P. Meehan (3.43%), and Walter Maetzler (2.86%) are the authors with the most articles published on the subject. Likewise, following Crane's classification (1969) and as shown in Figure 4, no author is considered a major producer since none of them has published more than 10 papers (Table 5) (Figure 4).

Table 5.
Authors by published articles

Authors	Articles
Howell, David R.	7
Meehan, William P.	6
Maetzler, Walter	5
Geritz, Johanna	3
Grooms, Dustin R.	3
Hansen, Clint	3
Helton, William S.	3
Hobert, Markus A.	3
Myer, Gregory D.	3
Schott, Nadja	3
Soangra, Rahul	3
Sosnoff, Jacob J.	3
Vuillerme, Nicolas	3
41 authors with 2 publications	82
797 authors with 1 publication	797

Note: Source: WOS; Table of own elaboration.

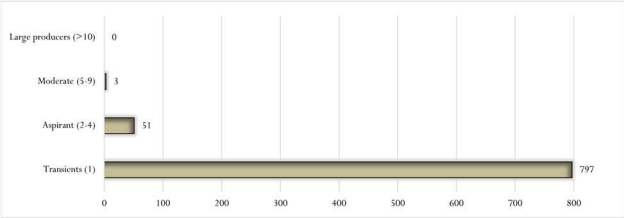

Figure 4. Crane's (1969) classification of authors**.** Note: Source: WOS; Figure of own elaboration.

Despite the fact that 851 authors participated in the research analyzed, there were a maximum of 22 authors in the same publication. Figure 5 shows that 171 of the publications (97.71%) were carried out by several authors through collaborations among them, in such a way that only 2.29% (n=4) of the articles were published by one author. In this case, articles by 3 authors (n=28) were the most common and represent 16% of the total number of publications. (Figure 5).

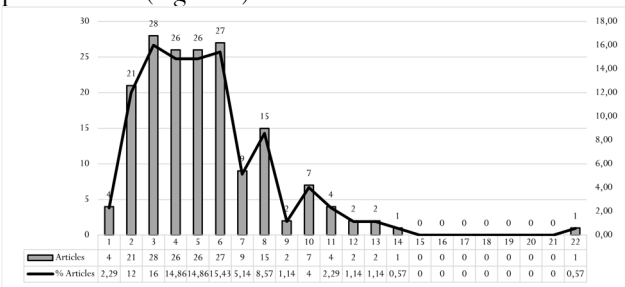

Figure 5. Authors per articule according to the number of publications made. Note: Source: WOS; Figure of own elaboration.

Despite naming David R. Howell, William P. Meehan, and Walter Maetzler as the main producers on dual-task and movement, they do not correspond with the results of the authors with the greatest impact. Their studies not only are not the most cited of the entire sample, but also, as detailed in Table 6, they do not appear among the most cited authors. David R. Howell is the thirteenth author in the ranking of the most cited authors with a total of 68 citations among all his publications (3.30%), while Walter P. Meehan is the twenty-third author with 65 citations (3.16%), and Walter Maetzler is in position number 164, with only 27 citations (1.31%).

In this case, the impact of the studies by Hagar Bernad-Elazari, Nir Giladi, Jeffrey M. Hausdorff, and Anat Mirelman stands out, since all of them hold the record of 150 citations each, that is, 7.29% of the total citations (n=2059) (Table 6).

Table 6.
Citations by author

Auhor	Articles	TC	Average
Bernad-Elazari, Hagar	2	150	75.00
Giladi, Nir	2	150	75.00
Hausdorff, Jeffrey M.	2	150	75.00
Mirelman, Anat	2	150	75.00
Maidan, Inbal	1	105	105.00
Shustack, Shiran	1	105	105.00
Besemer, Carmen	1	69	69.00
Gollhofer, Albert	1	69	69.00
Granacher, Urs	1	69	69.00
Wehrle, Anja	1	69	69.00
Muehlbauer, Thomas	1	69	69.00
40 authors with 50-68 citations	55	2404	43.71
89 authors with 30-49 citations	103	3472	33.71
181 authors with 10-29 citations	209	2958	14.15
103 authors with 5-9 citations	108	638	5.91
54 authors with 4 citations	56	216	3.86
63 authors with 3 citations	65	189	2.91
104 authors with 2 citations	104	208	2.00
62 authors with 1 citation	63	62	0.98
144 authors with 0 citations	149	0	0.00

Note: TC=Total cites; Average= Average number of citations per article; Source: WOS; Table of own elaboration.

Table 7 shows the articles with the greatest impact, those with the highest number of citations. These articles, all with 65 or more citations, are written by some of the authors cited above. In fact, the article with the most citations, 105, was written by the six authors who head the list of the most cited authors with more than 100 citations each. These are Hagar Bernad-Elazari, Nir Giladi, Jeffrey M. Hausdorff, Anat Mirelman, Inbal Maidan, and Shiran Shustack. Between them, they have a total of 810 citations, 39.34% of the total number of citations. The second article was written by the five authors who follow the previous ones in the list presented in Table 6. All of them have 69 citations. It is worth noting that they have only written this article on the subject. Therefore, according to Crane's (1969) classification, they are bystander authors, while the authors of the most cited article, since two of them have only one publication and the rest have two, are classified as bystanders and aspirants, respectively (Table 7).

Table 7.
Most cited articles

Article	TC	%TC	Quartile	Country	Sample	Paradigm
Mirelman, A., Maidan, I., Bernad-Elazari, H., Shustack, S., Giladi, N., & Hausdorff, J. M. (2017). Effects of aging on prefrontal brain activation during challenging walking conditions. Brain and Cognition, 115, 41-46. 10.1016/j.bandc.2017.04.002	105	5.10	Q4	USA	43	Cognitive-motor
Muehlbauer, T., Besemer, C., Wehrle, A., Gollhofer, A., & Granacher, U. (2012). Relationship between Strength, Power and Balance Performance in Seniors. Gerontology, 58(6), 504-512. 10.1159/000341614	69	3.35	Q2	Switzerland	24	Cognitive-motor
Hawkins, K. A., Fox, E. J., Daly, J. J., Rose, D. K., Christou, E. A., McGuirk, T. E., Otzel, D. M., Butera, K. A., Chatterjee, S. A., & Clark, D. J. (2018). Prefrontal over-activation during walking in people with mobility deficits: Interpretation and functional implications. Human Movement Science, 59, 46-55. 10.1016/j.humov.2018.03.010	65	3.16	Q4	France	48	Cognitive-motor

Note: TC=Total cites; %TC: percentage of total cites (N=2059). Source: WOS; Table of own elaboration.

Concerning the impact of the articles in general, as shown in Figure 6, although articles with 1 to 5 citations are the most abundant (n=70), those with the most citations are the ones that have been cited between 41 and 50 times (14.96%). In addition, 15.43% of the articles have obtained 0 citations, there are no articles cited between 71 and 100

times, and only one article exceeds 100, specifically with 105 citations, as indicated in the previous table. Likewise, as shown in Figure 7, the number of times the articles selected for analysis have been cited has increased exponentially in the last decade, culminating in 2022, which is the year with the most publications (n=29) and the most citations, i.e. 489 (23.75%) (Figure 6) (Figure 7).

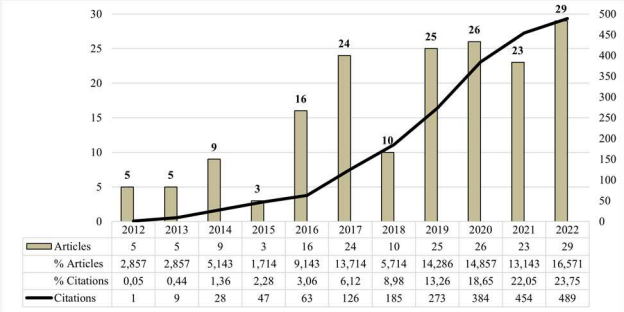

Figure 7. Citations by year of publication. Note: Source: WOS; Figure of own elaboration.

With regard to the articles, the keywords that the authors have used in their research are presented in Table 8, as well as the areas in which the search engine has classified these studies. The most repeated keywords among the authors were gait (35.43%) and dual-task. In the case of this last word, if those with and without hyphen were counted together, the result would be 40.57% of the total number of articles analyzed (n=175). (Table 8).

Table 8.
Keywords

Keywords	Articles	Sum total
gait	62	62
dual task	40	40
dual-task	31	31
attention	17	17
cognition	15	15
Parkinson's disease	12	12
aging	11	11
walking	11	11
Gait analysis	9	9
balance	9	9
falls	9	9
Not shown	8	8
Multiple sclerosis	8	8
EEG	7	7
Parkinson's disease	7	7
kinematics	7	7
rehabilitation	6	6
older adults	6	6
locomotion	6	6
4 keywords with 5 items	4	20
8 keywords with 4 items	8	32
14 keywords with 3 items	14	42
51 keywords with 2 articles	51	102
407 keywords with 1 article	407	407

Note: Source: WOS; Table of own elaboration.

Table 9.
Areas in which the articles are classified

Areas	Articles	%TS
Neurosciences & Neurology	78	44.57
Sport Sciences	31	17.71
Engineering	28	16.00
Rehabilitation	24	13.71
Orthopedics	20	11.43
Psychology	18	10.29
Geriatrics & Gerontology	17	9.71
Physiology	9	5.14
Other Topics	8	4.57
Instruments & Instrumentation	8	4.57
Chemistry	7	4.00
Biophysics	7	4.00
Science & Technology	7	4.00
Behavioral Sciences	5	2.86
MEDLINE	4	2.29
Research & Experimental Medicine	3	1.71
8 areas with 2 items	16	9.14
15 areas with 1 item	15	8.57

Note: TS= Total sample of articles (n=175). Source: WOS; Table of own elaboration.

Table 9 shows the areas in which the analyzed research has been classified. The area of Neuroscience & Neurology occupies the first place with 78 articles followed by Sport Sciences with 31 articles. (Table 9).

As debated in the introduction, the type of dual-task used in the studies depends on the activities performed. It receives a different name depending on whether, for example, the tasks have a motor, cognitive or rhythmic component. Figure 8 shows a classification according to the dual-task paradigm used in each study. The most used paradigm is the cognitive-motor paradigm (93.14%). (Figure 8).

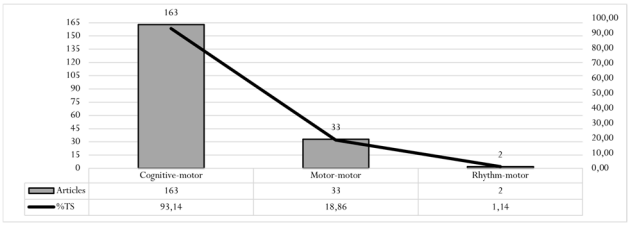

Figure 8. Dual. Task paradigms used in the articles. Note: Source: WOS; Figure of own elaboration.

More specifically, concerning the content of the articles, it is interesting to underline that most of the studies (25.14%) use a sample of between 11 and 20 subjects. As specified in Table 10, few studies exceed 150 participants. More specifically, 0.57% (n=1) evaluates a sample of 157, 384, and 500 and the record of sample participants in a study is 1054, which is a study from 2017 (Q2) and features 14 authors and 11 citations. (Table 10).

Table 10.
Subjects participating in each article

Sample	Articles	% Articles
0-10	5	2.86
11-20	44	25.14
21-30	37	21.14
31-40	24	13.71
41-50	11	6.29
51-60	13	7.43
61-70	10	5.71
71-80	8	4.57
81-90	4	2.29
91-100	5	2.86
101-110	3	1.71
111-120	2	1.14
121-130	2	1.14
131-140	0	0.00
141-150	3	1.71
151-200	1	0.57
201-300	0	0.00
301-400	1	0.57
401-500	1	0.57
500-1.000	0	0.00
More than 1.000	1	0.57
Total	175	100.00

Note: Source: WOS; Table of own elaboration.

Moreover, the main topics of the articles analyzed have been registered. As illustrated in Figure 9, the articles

dealing with walking are in first position (44%), followed by diseases and disorders that cause cognitive impairment, such as Parkinson's disease (n=33) or problems that arise at an old age (n=21), mainly the risk of falls due to lack of stability and coordination (19.43%). Most of the participants present either very advanced age or pathologies related to cognitive impairment, except for 5.14% of the articles, which deal with children, adolescents, or young adults, but who, in turn, present different disorders, such as Developmental Coordination Disorder (DCD), obesity, problems in motor development, cerebral palsy or concussion. The latter represents 30% of the articles in this sample, and there are only two articles with a sample of participants of healthy young people. (Figure 9).

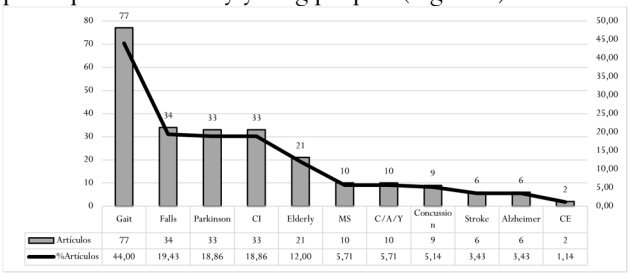

Figure 9. *Main topics*. *Note:* CI= cognitive impairment; MS= Multiple sclerosis; C/A/Y= children, adolescents and youth; CE= cardiovascular event. Source: WOS; Figure of own elaboration.

Table 11.
Data collection instruments

Instruments	Articles	Total sum	%TS
MMSE	37	37	21.14
TUG	32	32	18.29
MoCA	22	22	12.57
TMT	17	17	9.71
10MWT	16	16	9.14
EEG	11	11	6.29
GAITRite	9	9	5.14
UPDRS	8	8	4.57
fNIRS	8	8	4.57
GDS	8	8	4.57
H&Y	8	8	4.57
IMU	7	7	4.00
BBS	7	7	4.00
ABC	7	7	4.00
FES-I	6	6	3.43
EMG	6	6	3.43
MDS-UPDRS III	5	5	2.86
PCSS	4	4	2.29
6MWT	4	4	2.29
10 instruments with 3 items	10	30	17.14
23 instruments with 2 items	23	46	26.29
316 instruments with 1 item	316	316	180.57

Note: MMSE=*Mini-Mental State Examination*; TUG=*Timed Up &Go* Test; MoCA= *The Montreal Cognitive Assessment;* TMT=*Trail Making Test*; 10MWT=*10-Meter Walking Test*; EEG= Electroencephalogram; fNIRS=*Near-Infrared Spectroscopy*; GDS=*Geriatric Depression Scale*; H&Y=*Hoen &Yahr Scale*; BBS=*Berg Balance Scale*; ABC=*Activities-specific Balance Confidence*; FES-I=*Falls Efficacy Scale International*; EMG= Electromyography; MDS-UPDRS III=*Part II of the Movement Disorder Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale*; PCSS=*Post-Concussion Symptom Scale*; 6MWT=*6-Meter Walking Test*. %TS= Percentage of total sample of articles (n=175); Source: WOS; Table of own elaboration.

Finally, in respect of the methodology, the instruments used in the different studies, as can be seen in Table 11, are mostly from the field of neuroscience and neurorehabilitation. Among them, the Mini-Mental State Examination (MMSE, Folstein et al., 1983) stands out, used in 37 of the 175 articles analyzed (21.14%). This instrument was validated by Folstein et al. (1983) and is commonly used to measure the degree of cognitive impairment of a person. In fact, and as shown in the previous figure, it is a very recurrent topic among the items analyzed (18.86%). The third most used instrument (12.57%), The Montreal Cognitive Assessment (MoCA, Nasreddine et al., 2005), also aims to measure or detect cognitive impairment, in this case mild, of patients. The second most used (18.29%), the Timed Up & Go Test (TUG, Shumway-Cook et al., & Woollacott, 2000) is one of the most applied to measure and compare single and dual tasks. It is commonly employed with older adults or those with cognitive impairment, especially with people who are prone to falls, which is the second most studied topic in the articles (n=34), as detailed in the previous figure. (Table 11).

Discussion

The objective of this research was to carry out a bibliometric study of the scientific production published on dual-task and movement in high-impact search engines in the last 10 years, from 2012 to 2022. For this purpose, a sample of n=175 articles was obtained from the Web of Science search engine. The information detailed in the present study pretends to be useful for future research on this topic.

The findings of this research confirm that the subject under study is a relatively recent topic within the scientific production of high prestige. Indeed, 2022 has been the year of maximum production of articles. As previously stated, despite the decrease of articles in 2018, the number of citations has grown exponentially from 2012, with only 1 citation, to 2022, with 489, the year with the most publications (n= 22). This proves that, despite the decline, the interest and impact of dual-task and movement have grown in the last decade.

Moreover, most of the articles (97.14%) are published in English regardless of the fact that some of the authors do not use it as their first language. Nowadays, English is the language most accepted by the scientific community, although, on this subject, there are also articles written in Portuguese, Persian, and Korean. There are also articles published in more than one language. Some of them are in English and Portuguese, English and German, and there is one available in three languages: English, Portuguese, and Spanish. In this regard, it should be noted that English is the official language of some of the countries with the highest production, such as the USA and the United Kingdom.

Despite this, the country with the most articles published on the subject is Switzerland. This may be due to the fact that, as stated by the International Financial Analysts in their book on healthcare investment (2021), Switzerland is the country with the highest number of patent applications per capita, far above the rest of European countries, especially in medical technology and drugs and biotechnology, which indicates that it is a country

where healthcare professionals invest considerable time in research. Furthermore, as shown in the indicators on the OECD healthcare panorama (2021), in Switzerland, despite the prevalence of private healthcare, 11.3% of GDP is allocated to the healthcare system, while Spain is slightly above the average with 9.1%. Another possible cause of Switzerland being at the head of the scientific production of dual-task is the salary of physiotherapists, mostly specialized in rehabilitation, in which dual-task and movement are used. The salary of physiotherapists in Switzerland is one of the best paid in Europe, reaching five times the average salary of these professionals in Spain. This indicates that due to the high investment, the salaries and the applications for patents, Switzerland is a country with a great interest in health research and with resources, especially economic, that result in greater material resources useful to carry out more studies in this field.

The USA, China, and the United Kingdom are the countries at the forefront in terms of scientific contribution to the field of medicine. However, other countries are beginning to stand out in certain medical aspects. It is the case of Brazil (n=5) and South Korea (n=3), which are among the countries with the most publications after France (n=7) and Italy (n=5). In this sense, following the contributions of the book on healthcare investment (2021), South Korea tops the ranking with the highest number of hospitals per million inhabitants, as well as the number of medical consultations per capita, which indicates the interest in the quality of healthcare in the country. Brazil is below Spain in terms of scientific contributions to the field of medicine in general, but above it in pharmacology and toxicology. This confirms the boom that certain areas of medicine are starting to have in Brazilian health research.

As far as the journals are concerned, the contributions of Gait & Posture are the most significant, as it has the most publications on dual-task and movement. The main objectives of this journal include publications on gait and posture measurement techniques, gait and posture anomalies, the evolution of posture and bipedal locomotion, and articles on neurological and musculoskeletal functions in gait and posture. It is one of the most specialized journals on the subject analyzed in this article, which is why it is one of the journals to which most authors turn to publish and give greater visibility to their scientific productions on dual-task and movement. Furthermore, it is a journal in Q2 and it is published in Ireland, the fourth country with the highest number of publications after the United Kingdom.

The subject matter on which this bibliometric study is focused, as it has been argued previously, has begun to increase considerably in recent years. For that reason, most of the studies are very recent. Despite the fact that more and more articles are found among the first quartiles (Q1 and Q2), being the journals that collect more publications classified within Q2 (n=33), there are still many productions found in Q3 and, especially, in Q4 (n=29), as well as in secondary search engines. However, this is a topic that is causing great scientific interest in neurorehabilitation and neuroscience, which has favored not only the exponential growth of production and a greater impact of research but also the publication of these studies in search engines of greater rigor, international impact, and in the main quartiles.

Regarding the content of the articles, there are studies with a fairly small sample of participants. The predominant sample is between 11 and 20 subjects (25.14%). This may be due to the fact that the instruments most commonly used are very specialized, as well as very costly to implement. This is the case, among others, of electroencephalograms (n=11). However, these instruments provide very specific data on neuronal activation and are more reliable than tests that measure through direct and systematic observation. For this reason, the sample does not need to be representative of society for the results of the study to be generalized and have a greater impact since they can be demonstrated with scientific evidence.

It is also important to highlight the results about the paradigm that each of the studies has employed. As it has been shown in the previous section, the predominant paradigm is the cognitive-motor. In this particular study, it represents 93.14% of the investigations. In contrast, the low percentage of the motor-motor paradigm (18.86%) may be because this type of study focuses only on the kinesthetic part and motor skills, while the low production on the rhythmic-motor paradigm (n=2) may be due to the fact that, as previously stated, it is a relatively new paradigm, from the studies of Kim et al. (2017a, 2017b), as well as because of the lack of training of the researchers in terms of rhythmic notions. Likewise, for this same reason, the shortage of research on the cognitive-rhythmic-motor paradigm proposed by Romero-Naranjo et al. based on the BAPNE method could be justified, since the studies on it are very recent (2021e and 2023).

Nevertheless, it is important to emphasize the paradigms used because they are the basis for carrying out correctly any dual-task activity. Table 12 shows in more detail the different types of activities within each paradigm. (Table 12).

Table 12.
Most frequent activities according to each paradigm

Paradigm	Activities	Examples
Cognitive-cognitive	Two tasks with a cognitive component	Writing on a piece of paper while performing a verbal fluency task or having a conversation.
Motor-motor	Two tasks with a motor component.	Balance tasks: walking and carrying a glass of water in the hands; walking and holding a tray or holding two rings without rubbing against each other. Oculo-manual tasks: walking and marking a series of boxes on a sheet of paper or fastening buttons.
Cognitive-motor	One task with a cognitive component and another with a motor component	Walking and verbal fluency task (counting backwards the days of the week or the months of the year); walking and semantic fluency (generating words according to a task, for example, words beginning with a certain consonant); walking and categorical fluency (a type of semantic fluency but of a specific category, for example, only animals or fruits, etc.); walking and working memory task (remembering words, for example, heard in a text and counting them); walking and arithmetic task (performing n-back subtraction, addition, multiplication, division, etc.); walking with and without obstacles in the way.

Rhythm-motor	One rhythmic and one motor task	Walking while tapping (tapping at a certain rhythm with the hands and/or fingers) or walking while playing an instrument (usually a percussion instrument) following a rhythm.
Cognitive-rhythm-motor	One task with a motor component, one with a cognitive component and one with a rhythmic component	Walking while performing alternating hand rhythms and a verbal fluency task such as a conversation or reciting words or an arithmetic task such as addition or subtraction.

Note: Source: WOS analyzed articles; Table of own elaboration.

Given the great interest in the cognitive-motor paradigm, some of the most representative studies will be detailed below according to the type of activities carried out. Many authors, such as Boonyong et al. (2012), Falbo et al. (2016), Fok et al. (2011), Lundin-Olsson et al. (1997), Springer et al. (2006) or Tamura et al. (2018), among others, have worked on this paradigm. However, this analysis will focus on the articles included in the bibliometric review. The most frequent type of activity within the cognitive-motor paradigm in this study is verbal fluency, within which semantic and categorical fluency and the arithmetic task are incorporated. The gait and verbal fluency tasks correspond to 27.61% of the total number of items of the cognitive-motor paradigm (n=163) and 25.71% of the total number of items (n=175). As for arithmetic tasks, they represent 51.43% of the total number of items and 55.21% of the sample of items belonging to the cognitive-motor paradigm. In addition, within the arithmetic tasks, 86.67% correspond to n-back tasks, that is, subtracting or counting backwards given a certain number and a specific number to be subtracted successively, highlighting among them 7 n-back with 37.78% of the arithmetic publications (n=90) and 3 n-back tasks with 26.67%.

Finally, regarding the authors of the research analyzed, it should be noted that those with the greatest productivity do not coincide with those with the greatest impact. This may be because the impact of the research is not connected to the production of the research, but rather to the quality of the content. In this respect, the most cited authors (Bernad-Elzari, Giladi, Hausdorff. and Mirelmann) share their two publications, one in 2015 and the other in 2017, that focus on evaluating gait in adults through a cognitive-motor paradigm to check the effects that aging has on it, which is one of the most recurrent topics on the studies analyzed.

Moreover, the author David R. Howell has the highest number of published articles (n=7) and shares six of them with the second author with the most publications, William P. Meehan (n=6). Howell focuses all his publications dated from 2018 to 2022, like the authors with more impact, on a type of research that employs a cognitive-motor paradigm. In addition, he analyzes gait using a different sample, that is, children, adolescents, and young adults with and without a history of concussions. For that reason, these studies have a lower citation rate. Nevertheless, these incipient studies indicate that the direction of research on dual-task is beginning to change, presenting its benefits in a much younger population sample than the one commonly analyzed.

Conclusions

Some of the main limitations of the present study are, firstly, that only the productions of a single search engine have been analyzed since the number of articles and the analysis of these with mainly medical content was complex because of the lack of knowledge on this field, which was another major limitation. Secondly, during the course of the research, many articles were discarded due to the imprecision of the definition of the term dual-task, which led to the elimination of many articles that used other terms that, as stated in the introduction, are not considered synonyms. In addition, many investigations were also discarded because they did not specify the activities performed within each paradigm nor the instruments used. Therefore, it was not possible to identify whether the motor part really involved displacement or not.

Due to the great interest in the subject and the benefits demonstrated through scientific research on dual-task and movement, it would be advisable to carry out future research interventions in the educational setting without the need for the sample to present any kind of brain injury or disorder. A study of these characteristics would be useful to check whether by working on this type of activities since childhood certain brain areas are enhanced. This could help in the prevention or delay of cognitive impairment and possible motor problems, especially gait, in adulthood. Longitudinal studies would be a good start to learn about the benefits dual-task can have in the lives of people.

In conclusion, this study not only aims to present an overview of the scientific production published in high-impact search engines for it to be used in future research but also to raise awareness about this topic within the educational field, both among teaching professionals and the entire educational community, since working on dual tasks through movement from an early age could be very beneficial for the integral development of human beings.

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