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FEASIBILITY ANALYSIS TO EVALUATE THE EFFECT OF UNDERNUTRITION ON MEMORY AND PROCESSING SPEED IN SCHOOLCHILDREN FROM LOW-INCOME AREAS OF CARACAS*

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SUMMARY

During the first years of life it is essential to maintain adequate nutrition so that the structures of the nervous system can develop, guaranteeing optimal cognitive functioning in the future. In recent years, malnutrition in Venezuela has increased significantly, especially affecting low-income children who are in a sensitive period of their development. The aim of this study was to analyze the feasibility of an investigation to evaluate the effect of malnutrition on memory and processing speed in schoolchildren from poor areas of Caracas. The research design consisted of a feasible project, which began by detecting the needs that should be addressed in the different stages of the process. From these needs arose the realization of a pilot study, in which three tests of the *NIH Toolbox* neurocognitive battery associated to episodic memory, working memory and processing speed were administered to 11 children between 8 and 11 years old, diagnosed as eutrophic, malnourished or at risk of malnutrition. The results obtained from the analysis carried out, before and after the pilot study, took into account the processes, resources, project management and scientific feasibility, allowing us to conclude that the proposal is feasible, so we hope that it can serve as inspiration for future researchers interested in this sensitive aspect.

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* Article from an undergraduate thesis that obtained Honorable Mention in its defense.

Key words: malnutrition, cognitive processing, working memory, episodic memory, processing speed.

ABSTRACT

Throughout the early years of human life, adequate nutrition is essential for the nervous system to develop appropriately, guaranteeing optimal cognitive functioning. Unfortunately, in recent years, malnutrition has significantly increased in Venezuela, having an even more negative impact on low-class children going through a sensitive period of their development. The main goal of this study was to analyze the feasibility of a research proposal that could study the effect of malnutrition on memory and processing speed in school-age children from low-class areas of Caracas. The study began considering the needs of the different stages of the research process. From this assessment came the idea of carrying out a pilot study using three tests from the cognitive domain of the NIH Toolbox: episodic memory, working memory, and processing speed. These tests were administered to 11 children between 8 to 11 years old, diagnosed as eutrophic, undernourished, or at risk of undernourishment. The results obtained from the analysis, both before and after the pilot study, considered the processes, resources, management, and scientific viability of the proposed methodology, allowing us to conclude that the research proposal is feasible and might become a strategic contribution to future researchers interested in this sensitive topic.

Key words: Malnutrition, cognitive process, working memory, episodic memory, processing speed.

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CONTENIDO

INTRODUCTION

The anatomical and functional development of the nervous system is a very complex process that is key to optimal performance in the tasks we must perform on a daily basis. Every time a person thinks, makes a decision and converts it into action, he or she is using his or her nervous system. Mental processes such as thinking, perceiving, imagining, imagining, speaking, acting and planning are used by our brain to generate and process knowledge, which we know as cognition (Ward, 2015).

Although development extends into early adulthood, the period of childhood is particularly important for building a healthy brain and is therefore known as a sensitive period (Tierney and Nelson, 2009). Healthy development during childhood, spanning the physical, socioemotional, and cognitive domains, exerts a notable influence on well-being, mental health, and the abilities to express oneself and acquire knowledge (Irwin et al., 2007). During this stage, the brain grows at a very high rate that is not repeated at any other time in life, increasing synaptic density and striving to complete the myelination process (Homae et al., 2010). In addition, the cerebral cortex possesses high neuronal plasticity, which allows it to adapt and modify neuronal circuits in response to new learning and experiences (Hernández-Muela et al., 2004).

However, without an adequate level of nutrition, irregularities in the development and functioning of brain structures can occur, leading to delays in neurodevelopmental milestones (Homae et al., 2010). This phenomenon is known as undernutrition and consists of a severe weight deficit caused by insufficient food intake (Food and Agriculture Organization of the United Nations; FAO, 2014). This is one of the main challenges Venezuelan children face in achieving optimal cognitive development. According to the World Food Program (WFP, 2020), one in three people in Venezuela is food insecure and in need of assistance; with children, pregnant women and older adults being the most affected.

Among the cognitive processes that are most affected with malnutrition are episodic memory, working memory and processing speed, which form the basis of the present article.

Episodic memory stores information related to past events and the temporal-spatial relationships of these events, allowing humans to relive previous experiences and use them as the basis for new actions (Martin-Ordas and Call, 2013). This type of memory is one of the last to develop (it presents great changes during the first twenty years of life), one of the first to begin to deteriorate and the most vulnerable to neuronal dysfunctions. Operations to retrieve episodic memory involve the participation of multiple brain regions of the temporal lobe and prefrontal cortex (Tulving, 2005; Weintraub et al., 2013).

Working memory is defined as a "brain system that provides temporary storage and manipulation of information necessary for complex cognitive tasks, such as language comprehension, learning and reasoning" (Baddeley, 2003, p. 829). It is a storage mechanism that only comes into play when a specific type of information is required to perform a wide range of behaviors, such as perception, problem solving, and control of various actions (Ballesteros, 1999; Ji Ma et al., 2014).

Working memory is related to executive and inhibitory control processes, since in order to process specific information it is necessary to maintain a certain degree of attention and resource management (Carrigan and Barkus, 2016). Even, this type of memory is key to program effective responses to new situations and is an essential component in fluid intelligence (Cowan, 2016).

Information processing speed is a cognitive process related to the time it takes an individual to capture and integrate information during problem solving, as well as to the speed with which he/she performs cognitive functions such as identifying an object, making decisions, or making simple discriminations between objects or images correctly (Kail and Salthouse, 1994). It is considered as the main component that determines individual differences in global intelligence and the basis of word and visual stimuli recognition, reading comprehension, and verbal reasoning (Cameron et al., 2014). For this reason, it is one of the most sensitive indicators in cognitive dysfunction. When impaired, it also generates consequences in the functioning of other complex activities such as memory and reasoning (Weintraub et al., 2013; Kail and Salthouse, 1994).

Despite the fact that malnutrition is one of the most urgent problems in Venezuelan society and that, according to experts, the long-term sequelae of current nutritional states may be irreversible (UCAB et al., 2020), little scientific research has been conducted in the country to determine the effect of the severe food crisis on the cognition of school-age children, so that the knowledge obtained can be used for the development of preventive and rehabilitative measures. That is why the present research sought to analyze the feasibility of a study to evaluate the possible effects of malnutrition on cognitive processes such as episodic memory, working memory and processing speed.

METHODOLOGY

The present study corresponded to a feasible project-type research design, which began with the intention of determining the most suitable site to evaluate the effect of malnutrition on certain aspects of cognitive processing. This search led us to the Centro de Atención Nutricional Infantil de Antímano (CANIA), located in Caracas.

After several meetings and covered by the Cooperation Agreement signed between CANIA and UNIMET on October 10, 2019, an interaction began that led to the attention of common needs between both institutions. This became evident through a Google form, in which each member of the Management Team was able to express their opinion regarding the importance of carrying out this type of research and the feasibility of the proposal.

This instrument consisted of 18 questions, 7 of which were designed using the Likert scaling format to determine the needs and interest of CANIA, as well as those of the research team. The rest of the questions were formulated to obtain yes or no answers, in order to know and validate aspects related to the institution that could contribute to the feasibility analysis, as suggested by Learmonth and Motl (2018), Thabane et al. (2010) and Tickle-Degnen (2013).

The next phase consisted of a pilot study with a non-experimental, ex post facto design. With respect to temporality, it was a transectional or cross-sectional design study.

The pilot study sample, selected on a non-probabilistic basis, was composed of 11 children between the ages of 8 and 12 years old, residing in popular areas of the Metropolitan Area of Caracas. These children attended the Family Orientation and Strengthening Program (PROFAM), located in Caracas, in order to receive nutritional care due to malnutrition or nutritional risk and social vulnerability. Although this was the initial site of contact for the purposes of the pilot study, for various reasons beyond the control of PROFAM and the research team, mostly related to the difficulty of reaching a sample of sufficient size in the necessary time and that would also allow a rigorous statistical analysis, the feasibility analysis presented below assumes that the definitive study will be carried out at the CANIA headquarters, considering that both institutions serve children in similar socio-demographic and malnutrition conditions.

It should be noted that when it is a pilot study, it is common to use a smaller sample size than the planned sample, according to the available resources, since the aim is not to conclude significant results of a hypothesis, but to learn about possible problems related to the methodology to be implemented (Thabane et al., 2010).

The variables present in this study were malnutrition, as an independent variable, and memory and processing speed, as dependent variables. The nutritional status of the participants was obtained through a triage form prepared by PROFAM staff. On the other hand, memory and processing speed were assessed by three cognitive tests of the neurobehavioral battery called NIH *Toolbox for the Assessment of Neurological and Behavioral Function*, in its Spanish version.

The *National Institutes of Health* (NIH*),* in the United States, created the *NIH Toolbox in order to* respond to the need to find a "common language" in which to compare results between different studies. This tool is administered via an iPad to subjects between the ages of 3 and 85 years. It also saves researchers' time, as it facilitates the partial or complete administration of the tests in their different domains (cognitive, emotional, sensory and motor). If it were to be administered completely, the time of use is approximately two hours (Weintraub et al., 2013).

The tests administered in the present pilot study were the *Pattern Comparison Processing Speed Test*, the *List Sorting Working Memory Test* and the *Picture Sequence Memory Test*, in that order.

In the Pattern Comparison Processing Speed test, each participant is asked whether two visual patterns are the same, marking "yes" if they are, or marking "no" if they are not. As the test progresses, the complexity and number of stimuli vary to ensure variability in participant performance. This test requires 3 minutes of administration, with a maximum possible score of 130 correct items (Weintraub et al., 2013).

The Task List Ordering Working Memory test displays a series of stimuli in the form of objects that are presented visually on the iPad screen, accompanied by an audio that verbally says the name of the objects. Participants must verbally repeat the stimuli to the examiner, ordered by size. As the test progresses, the number of items and categories increases and with it their difficulty. The administration of this test lasts approximately 7 minutes and the results correspond to the total number of correct items across all attempts, with a maximum possible score of 26 correct items (Weintraub et al., 2013).

Finally, the Image Sequence Ordering Memory Test consists of presenting a set of images containing objects and activities, which appear in a sequence at the edge of the iPad screen. Subsequently, these images return to the center in an unordered manner. Participants must return the images to their corresponding spaces, arranging them in the sequence demonstrated above. Each participant must complete two trials, whose sequence lengths vary from 6 to 18 images, depending on age. At the end of the test, the instrument yields two scores. The first corresponds to the number of pairs of adjacent images that the subject manages to remember correctly in the first trial, the maximum possible score being 17 correct items for the ages included in this study. The second consists of a comparative score that takes into account whether there was any improvement between the results obtained in the first and the second trial; that is, it shows whether any learning process occurred. This score is expressed automatically on an approximate scale between 200 and 700 points for the ages covered in this study (NIH and Northwestern University, 2016). The administration time for this test is approximately 10 minutes (Weintraub et al., 2013).

Regarding the analysis of the results, descriptive statistics were used to calculate the mean and standard error of the results obtained when the tests were administered to each group. Secondly, it was determined whether the data met a Gaussian distribution criterion, for which the Kolmogorov-Smirnov test was applied. Accordingly, and considering the small sample size, the Mann-Whitney *U* test was applied to determine whether there were significant differences between the results of each group. For this purpose, the statistical program GraphPad Prism, version 9.0, was used, which additionally has the advantage of being a graphing program.

Finally, a qualitative analysis related to the conditions and sociodemographic variables that could have interfered with the results was performed. This analysis was based on the parents' comments prior to testing and the information provided through the aforementioned triage form.

RESULTS AND DISCUSSION

Results of the form answered by CANIA's Management Team

In the first place, the importance of knowing in greater depth the effects that malnutrition can have, specifically in relation to the cognitive area, was validated, which can help to take preventive and prophylactic measures, both at the individual and collective level. In addition, it was noted that this knowledge can also help to conveniently identify the return on investment in nutritional care programs, contribute to accountability and design specialized cognitive rehabilitation strategies.

Secondly, it was confirmed that the present work represents a mutual benefit, both for the UNIMET research team and for CANIA, since both institutions pursue common academic and research purposes and cooperation between them represents an opportunity to use related services, as well as the use of existing human and physical resources. In addition, this could open doors to new academic and scientific advances that would not only benefit both institutions, but also the population served that is suffering from malnutrition.

Thirdly and finally, the form corroborated that the daily dynamics of the institution allow the proposed research to be feasible, since children diagnosed with malnutrition and with the ages included in the proposal attend, there is a team of nutritionists and pediatricians who perform nutritional diagnoses, there are time slots where children can take cognitive tests before they eat their morning snack (so as not to affect their nutritional status), and the advantages of using the *NIH Toolbox* instrument to evaluate cognitive processes in school children are known. In addition, it was affirmed that CANIA agrees to open its doors to students to continue conducting research related to malnutrition and the cognitive impairment it induces, contributing to the generation of knowledge in these areas.

Results of the pilot study

The pilot study consisted of a sample of 11 children who attended PROFAM, whose characteristics are summarized in Table 1.

Table 1. Description of the sample of subjects evaluated in the pilot study.

Subject	Age at time of evaluation	Sex	Diagnosis	Time for the last meal	Evaluation Time	Mother's schooling
1	11,1	M	Eutrophic	7:00 am	10:00 am	Basic
2	8,1	M	Eutrophic	7:00 am	10:25 am	Basic
3	10	M	Eutrophic	Breakfast	2:30 pm	TSU
4	11	F	Risk of malnutrition	Breakfast	2:50 pm	1st semester University
5	8	M	Risk of malnutrition	Breakfast	2:00 pm	1st university semester
6	11	M	Risk of malnutrition	8:00 am	12:43 pm	Basic
7	10,9	M	Risk of malnutrition	8:00 am	12:42 pm	Basic
8	12	M	Risk of malnutrition	Breakfast	2:30 pm	TSU
9	9,5	M	Acute malnutrition	8:00 am	1:20 pm	Basic
10	9	F	Acute malnutrition	Lunch	3:55 pm	University
11	8	M	Acute malnutrition	Lunch	4:03 pm	University

Results are presented according to diagnostic criteria. Age at the time of evaluation is reflected in years; M = Male; F = Female.

Pattern Matching Processing Speed Test

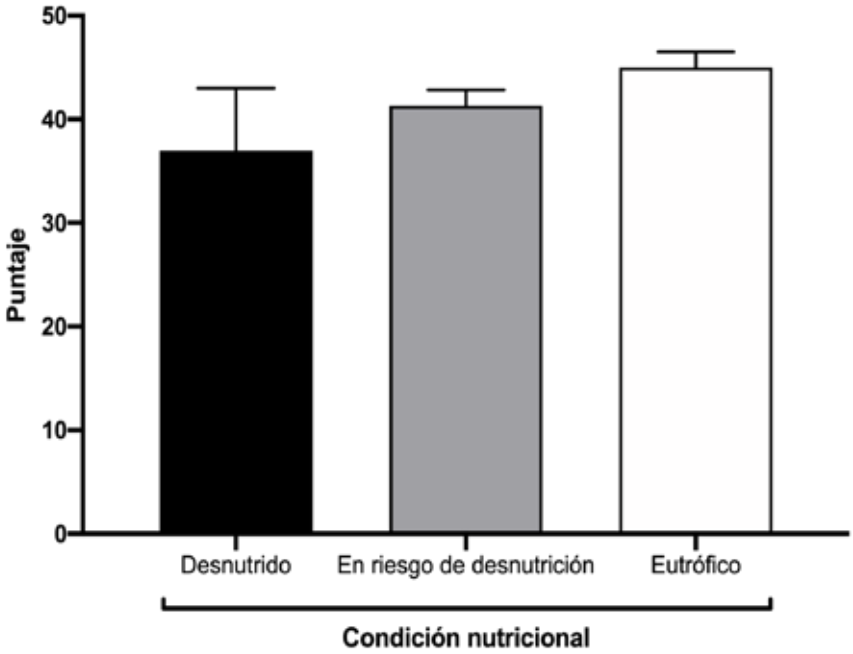
The subjects evaluated with this test were the 11 children described above. To compare the difference in results between the different nutritional diagnoses, the means and standard error were calculated for each of the groups of participants. Table 2 presents the score that refers to the number of items answered correctly in a period of 90 seconds. As mentioned above, this score falls within a scale of 0 to 130 points (NIH and Northwestern University, 2016).

Table 2. Mean and standard error of the results of the NIH Toolbox neurobehavioral battery tests.

Test	State Nutritional	Score	Comparative Score
		x̄±EEM	x̄±EEM
Pattern Matching Processing Speed	Malnourished (n=3)	37 ± 6	N/A
	At risk of malnutrition (n=5)	41,33 ± 1,50	N/A
	Eutrophic (n=3)	45 ± 1,50	N/A
Working Memory by Task List Ordering	Malnourished (n=1)	10 ± 0	N/A
	At risk of malnutrition (n=2)	12, 50 ± 0,50	N/A
Memory by Image Sequence Ordering	Malnourished (n=3)	14,50 ± 3,84	530,91 ± 72
	At risk of malnutrition (n=5)	9,75 ± 4,05	504,99 ± 52,45
	Eutrophic (n=3)	6,33 ± 0,88	424,88 ± 11,38

For better visualization, these results were represented graphically in Figure 1.

Figure 1. Pattern Matching Processing Speed Test scores.



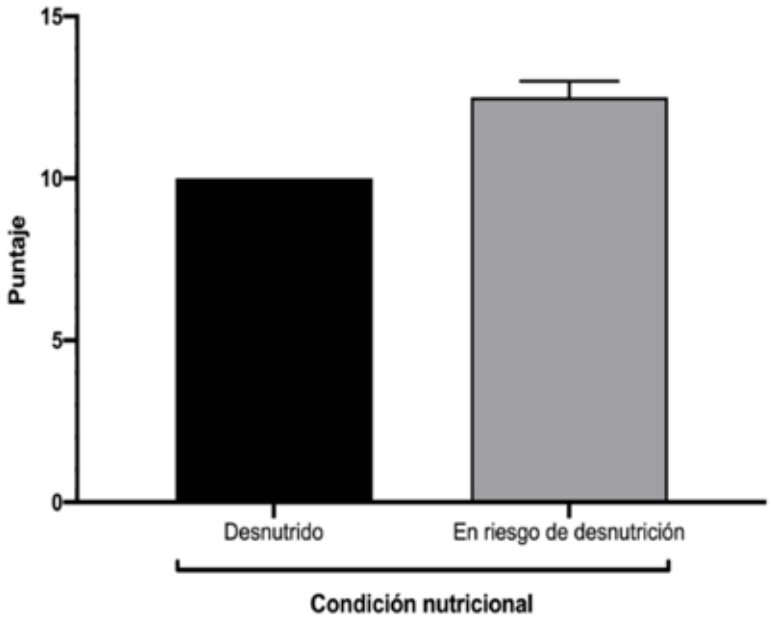
The columns represent the values obtained in the test, expressed as $\bar{x}$±EEM. Children in malnourished condition are represented by the black color bar, those at risk of malnutrition by the gray bar, and eutrophic children by the white bar ($\bar{x}$±EEM = mean ± standard error of the mean).

Although the Mann-Whitney *U* test did not reveal statistically significant differences between each group (p=0.3036; *U=3*.500), it was evident that the undernourished children performed less well. If this trend is maintained in a large-scale investigation, it would help to understand how malnutrition could be causing alterations in the brain structures described above, in their level of metabolism and in the associated neurotransmitters, resulting in a possible deterioration at the cognitive level (Levitsky and Strupp, 1995).

Task List Ordering Working Memory Test

The subjects evaluated in this test were three children belonging to the same group of participants described above. The results were obtained through the score that refers to the number of items answered correctly on a scale from 0 to 26 points (NIH and Northwestern University, 2016), as shown in Table 2. In this case, as one of the groups has only one participant, no statistical tests were performed to compare the groups. These data were also plotted in Figure 2.

Figure 2. Scores obtained in the Task List Ordering Working Memory Test.



The columns represent the values obtained in the test, expressed as $\bar{x}$±EEM. Children in a malnourished condition are represented by the black bar and those at risk of malnutrition by the gray bar ($\bar{x}$±EEM = mean ± standard error of the mean).

The results suggest that the test is able to discriminate the changes between both conditions, reflecting a tendency of lower performance in working memory in undernourished conditions. Although no significant conclusions can be drawn from these results, the results allow us to account for the feasibility of administering the test in children with both nutritional diagnoses. Furthermore, as has been previously reported (Morgan, 2015), these results give indications that malnutrition can generate deficits in working memory, producing delays in the development of the prefrontal cortex.

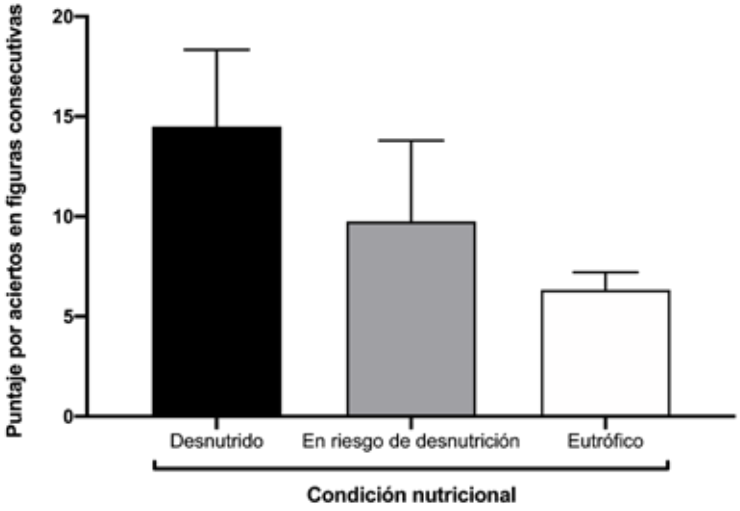
On the other hand, the trend evidenced in the results of this test resembles the findings of the study by Ocampo (2011), in which working memory and processing speed were similarly affected in the face of nutritional deficiencies in the participants.

Finally, with regard to this test, it is important to consider that the children in both groups are of similar ages, their mothers have a basic level of schooling and have equivalent fasting times, so it is not feasible to analyze the influence of these variables given the sample size. Nevertheless, it is still vitally important to take these considerations into account when conducting future research.

Picture Sequence Ordering Memory Test

The subjects evaluated with this test were the same 11 children to whom the processing speed test was administered. Table 2 shows the results obtained by calculating the mean and standard error of the different groups. These data were also represented in bar graphs. Figure 3 represents the score obtained by matching consecutive figures in the sequence of images, while Figure 4 represents the results of the comparative score, taking into account the learning between the two trials.

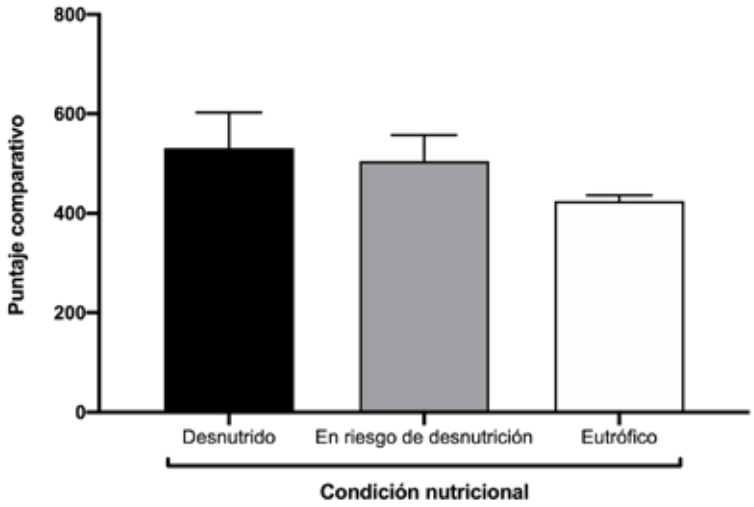
Figure 3. Scores obtained from consecutive figure hits in the Picture Sequence Ordering Memory Test.



The columns represent the values obtained in the test, expressed as $\bar{x}$±EEM. Children in malnourished condition are represented by the black color bar, those at risk of malnutrition by

the gray bar, and eutrophic children by the white bar ($\bar{x}$±EEM = mean ± standard error of the mean).

Figure 4. Comparative scores obtained from the results of the Image Sequence Ordering Memory Test.



The columns represent the values obtained in the test, expressed as $\bar{x}$±EEM. Children in malnourished condition are represented by the black color bar, those at risk of malnutrition by the gray bar, and eutrophic children by the white bar ($\bar{x}$±EEM = mean ± standard error of the mean).

Although the Mann-Withney *U test did* not yield statistically significant differences between each group (p=0.3929; *U=4*.000), the results show a tendency for children with a diagnosis of malnutrition to perform better. At first glance, these results may seem contradictory; however, they invite us to consider the influence of other variables that may have modified the outcomes.

First, there is the mother's schooling. In this study, the mothers of the malnourished children have a higher level of schooling, being the only ones who completed university education. This is related to studies in which there is a significant positive interaction between the parents' educational level and the performance of memory-related activities (Matute et al., 2009).

Another aspect to consider is the effect of a meal close to the time of the assessment, since children with malnutrition were those who ate a full meal a few hours before the assessment. The consumption of a meal or snack may affect cognitive performance as a function of changes in blood glucose levels. Since glucose is the essential component in the brain's metabolic processes, eating a meal may generate a transient increase in blood glucose concentration sufficient to induce an artifactual change in memory at the time of assessment (Mahoney et al., 2005).

The above is consistent with the findings of Aristizábal et al. (2018), who, in their studies on the effects of malnutrition on memory processes in children aged 6 to 10 years, found that working memory is affected regardless of the school grade of the participants, as evidenced in the previous test. On the contrary, they found that in episodic memory there is a high influence of social and environmental factors, in addition to the nutritional level. However, according to what is shown in Figure 4, it seems that there was greater learning (when comparing the two trials of the test) in the groups of children at risk of malnutrition and eutrophic children, rather than in children with malnutrition. In fact, it is observed that in the comparative score results there are fewer differences between the three groups compared to the initial score results.

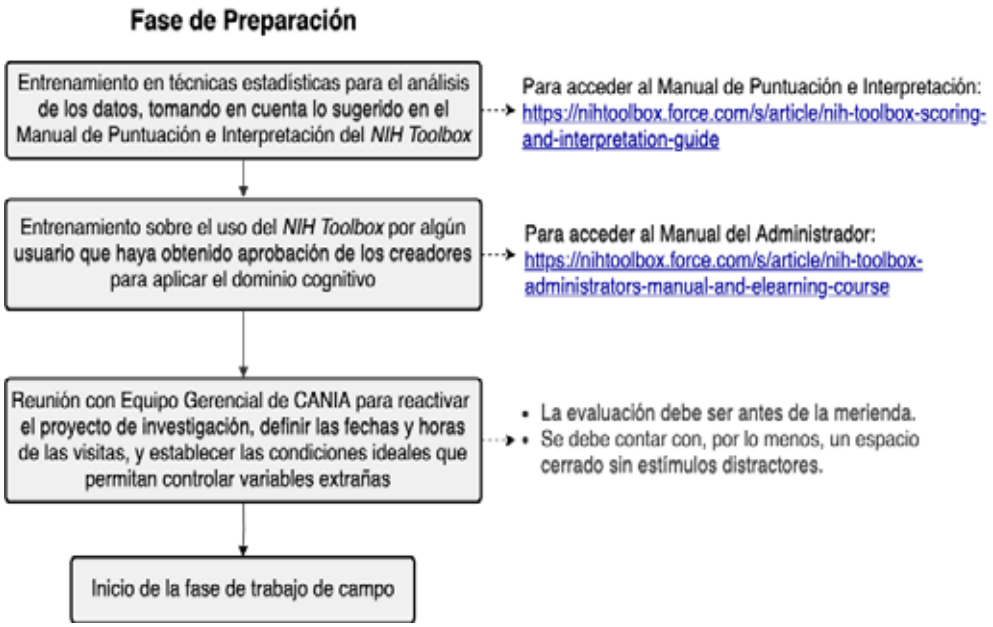
It should be noted that this was the last test applied to each child and, in turn, is the test that involves the greatest cognitive load. Therefore, it could also be influenced by a fatigue and exhaustion effect, although one of the intentions of the *NIH Toolbox* is to minimize these effects through the playful participation derived from the use of iPads.

Finally, it is important to remember that since this is a small sample, the results are even more affected by external variables. However, despite the fact that statistically significant conclusions cannot be drawn, these results allow us to identify those variables that should be taken into account and controlled in future research, as well as to know what other aspects influence cognitive performance that would not have been taken into account in the first instance.

Methodological proposal

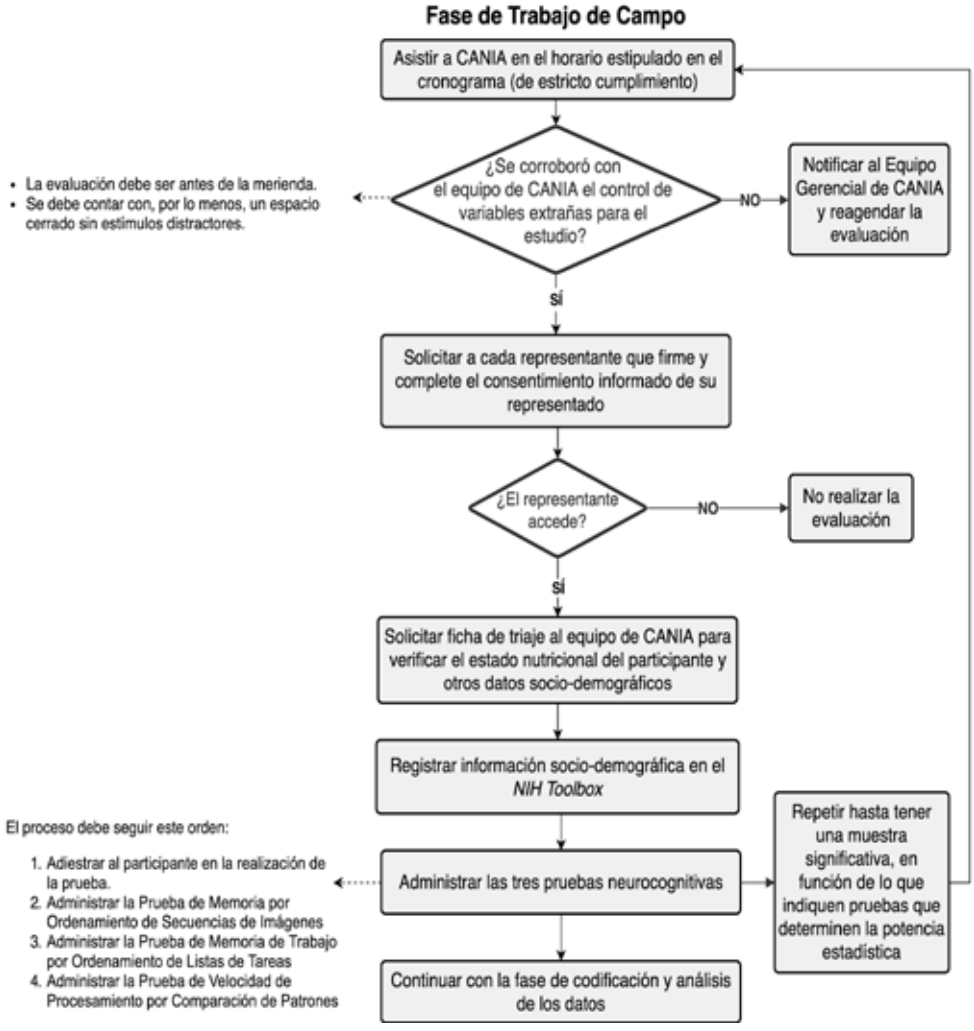
After analyzing the results of the form answered by the CANIA Management Team and those derived from the pilot study, and considering the initial research objectives, a methodological proposal was developed for the study of the effect of malnutrition on memory and processing speed in children between 6 and 10 years of age who attend CANIA and come from popular areas of Caracas. Figure 5 summarizes the preparation phase, which is estimated to last approximately two months.

Figure 5. Step-by-step for the large-scale preparation phase.



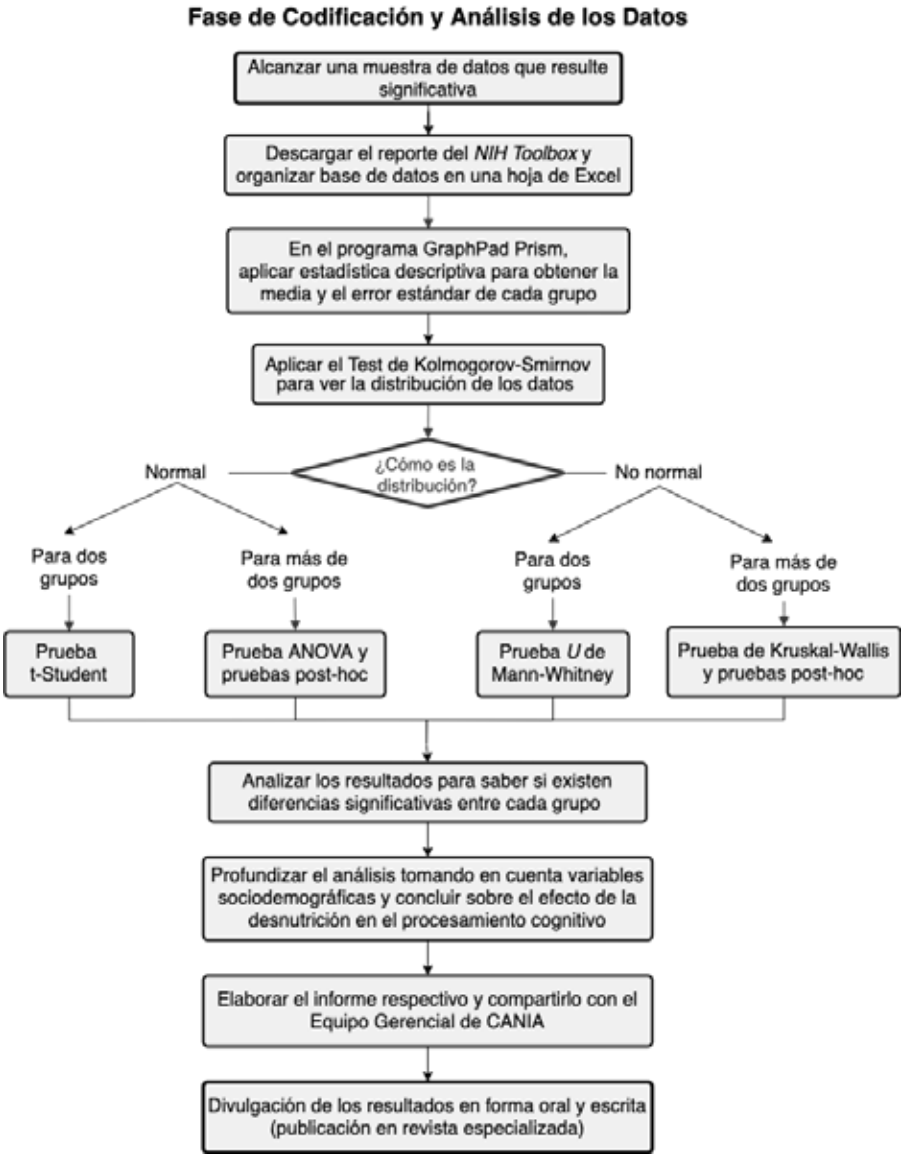
Once the guidelines for action have been defined with the CANIA team, the fieldwork phase, detailed in Figure 6, will begin. It is estimated that this fieldwork phase will last approximately four months, which is the one that will take the most time for the development of the research.

Figure 6. Step-by-step of the fieldwork phase of the large-scale research.



Finally, we would proceed with the data coding and analysis phases, which are represented in Figure 7.

Figure 7. Step-by-step of the coding and analysis work phase of the large-scale research data.



Feasibility analysis of the proposal

To know whether the proposal developed above is feasible, various authors from different areas of study, such as Learmonth and Motl (2018), Thabane et al. (2010) and Tickle-Degnen (2013), identify four aspects that should be taken into consideration: processes, resources, project management and scientific feasibility.

Processes

When talking about *processes*, reference is made to the step-by-step needed to carry out the main study (Tickle-Degnen, 2013). First, it is considered that a clear and sufficient criterion was defined for the sample, which corresponds to children aged between 6 and 10 years, both malnourished and eutrophic, from popular areas of Caracas attending CANIA. This age range was chosen to ensure a significant size without being too restrictive, but guaranteeing that all participants belong to the same sensitive period of development in terms of the cognitive functions to be evaluated, specifically, the period of concrete operations according to Jean Piaget's theory of Cognitive Development.

Regarding the feasibility of achieving a significant size in the stipulated time, the pilot experience showed that this was not going to be possible in PROFAM and therefore it was proposed to carry out the research in CANIA, an institution that receives acutely malnourished children under 18 years of age on a weekly basis, in its Semi Boarding Care program. In addition, since it is located in the same area where populations vulnerable to malnutrition belong, transportation problems are minimized. All this was validated in the form answered by CANIA's Management Team.

Within the same form, 100% of the participants affirmed that CANIA has partnerships with educational centers in the area attended by eutrophic children between the ages of 6 and 10, which ensures that they can monitor performance on the *NIH Toolbox* tests in both nutritional diagnoses.

With respect to the participants' ability to understand the questions and instructions, this is ensured in two ways. First, the instrument is designed for individuals between 3 and 85 years of age and is adjusted to the age of the participant. Second, each test has a practice phase, in which participants have the opportunity to be trained in the different steps to be followed.

Finally, with respect to the time of each evaluation, the three tests to be administered have a total duration of approximately 20 minutes, which is considered an adequate time to avoid the effects of fatigue or exhaustion in the participants.

Resources

Analyzing the feasibility of *resources* involves answering whether there is the physical capacity to assess the desired number of participants, whether feasible time frames have been established, whether the necessary equipment is in place to carry out the study, and whether there is motivation on the part of the institutions involved to support the research (Tickle-Degnen, 2013).

With respect to the physical capacity to be able to evaluate the desired number of participants, in the pilot experience it was identified as an ideal condition to have two similar spaces, since this would allow the simultaneous evaluation of two children, each with one researcher. Unfortunately, it was not possible to have this condition in PROFAM, which became an obstacle to reaching the desired sample size.

Likewise, 100% of the participants of the Management Team responded that CANIA has a physical space that can be used for the application of cognitive tests, without distracting stimuli. They also responded that, within the daily dynamics of the institution, there are time slots where children can perform cognitive tests to contribute to this research project. In addition to this, it is also important to mention the commitment of CANIA for the free access of researchers to these spaces, as agreed during the preparatory meetings.

In order to guarantee that the time periods are adjusted to the capabilities of the researchers, it is expected that they have time availability of at least two mornings a week and, if they are students, that they are in the 11th or 12th trimester of the Psychology course and, therefore, that they have a low academic load that allows them to attend at least two mornings a week at the institution.

With respect to equipment, the Neuroscience Laboratory of the Universidad Metropolitana has four iPads that were kindly donated by Empresas Polar for research and knowledge generation purposes, two of which can be made available for use in the proposed research. It should also be noted that the license of the *NIH Toolbox* instrument was donated to Professor Victor Tortorici, for one year, by the National Institutes of Health of the United States and has subsequently been renewed by UNIMET in order to carry out the research project.

Finally, the motivation and commitment of CANIA in this research work was demonstrated with the signing of the Inter-institutional Cooperation Agreement between CANIA and UNIMET and was later validated with the form answered by its Management Team, where they affirm that the institution agrees to open its doors to students to carry out this research.

Project Management

The evaluation of *project management* seeks to determine the viability of the human capital that will carry out the study and its capacity to carry it out successfully, as well as everything related to the management of the data collected (Learmonth and Motl, 2018).

First of all, researchers are expected to be professionals or students in the last year of their Psychology degree, so they should have knowledge in the area of neurosciences and cognitive processes, as well as quantitative research methodology and statistics. On the other

hand, it is expected that, as in the pilot experience, the researchers will receive training on the use and administration of the *NIH Toolbox* instrument from Professor Victor Tortorici, who in turn received a training program supervised by Dr. Richard C. Gershon, from Northwestern University, representative of the National Institutes of Health of the United States and leader of the team that developed the *NIH Toolbox*.

With regard to whether there are formats or structures that facilitate documentation of the study progress, there is a model informed consent form that should be given to the representatives prior to the evaluation. It should also be noted that the *NIH Toolbox* instrument has a sociodemographic characteristics form that must be filled out for each of the participants prior to the administration of the test battery and that can be corroborated with the information obtained in the informed consent forms. This information is retrieved by downloading the reports with the results of each participant issued automatically by the *NIH Toolbox*. This ensures that the information is recorded, processed and analyzed correctly.

Scientific Feasibility

As a last aspect to be evaluated, *scientific feasibility* refers to everything related to the safety of the study and its results (Learmonth and Motl, 2018). Regarding this, Tickle-Degnen (2013) proposes the following questions: is it possible to standardize the frequency, intensity and duration of each intervention or assessment? Are validity and reliability criteria taken into account in the instruments to be used? What extraneous variables can influence the results?

First, with respect to the frequency and duration of each evaluation, since these are standardized tests, it is estimated that the evaluation of all subjects will be similar, around 20 minutes in total for each one, as occurred in the pilot experience with the participants.

Secondly, different validation studies were taken into consideration, both convergent and divergent, and reliability studies, which verify the validity and reliability of the tests to be used. Although these studies were conducted in North American population, in our country Lopez and Marchionna (2019), conducted an investigation in CANIA, with a sample of children, both malnourished and eutrophic, in which they administered two tests of the *NIH Toolbox* and found convergence with the Symbol Search subtest of the Wechsler Intelligence Scale for Children-IV (WISC-IV) and with the Peabody Picture Vocabulary Test. It is worth mentioning that these authors were the first researchers to administer this neurobehavioral battery in Venezuela, with children in the same age range and in the same institution as the one proposed.

In addition, the pilot experience allowed us to verify that the instrument can be administered without any problem, in its Spanish version, and can be easily understood by the participants. Similarly, the results obtained and analyzed in the pilot study seem to indicate that the instrument not only manages to detect differences in children's cognitive performance in memory and processing speed, but also gives indications of how these processes can be affected by nutritional status and even by other sociodemographic aspects. Finally, the pilot experience made it possible to identify which variables should be taken into account in future research, such as the effect of the pre-evaluation snack, the mother's level of schooling and socioeconomic conditions, since they may influence the results obtained.

CONCLUSIONS

Based on the results obtained, both in the questionnaire answered by the members of the different management of CANIA, and in the pilot study, as well as in the theoretical aspects that contemplate a feasible project, it was possible to determine the feasibility of a research project that would allow knowing the effect of malnutrition on memory and processing speed in children between 6 and 10 years old, who attend the Children's Nutritional Attention Center of Antímano (CANIA). In this way, the general objective of the research was fulfilled. This resulted in the elaboration of a feasible methodological proposal presented in a set of flow charts, which will allow the information to be easily understood and used by those who carry out the research on a large scale.

To achieve this general objective, through a series of familiarization visits to CANIA and the questionnaire answered by its Management Team, it was possible to determine the interest of this institution in contributing to the proposed research. Likewise, in this process it was possible to describe a series of mutual needs that can be covered by this research, such as the importance of knowing the effects of malnutrition on cognitive processes in order to take preventive and prophylactic measures, to conveniently identify the return on investment in nutritional care programs and to design specialized strategies for cognitive rehabilitation.

These data collection techniques also confirmed that CANIA's daily dynamics allow us to guarantee access to a significant sample that meets the established exclusion criteria, contributing, in this case, to the feasibility of the processes.

During the pilot study, optimal conditions were identified to carry out the proposed research. It was corroborated that the *NIH Toolbox* can be administered in a sample of school-age children from popular areas of the Metropolitan Area of Caracas, with the advantage of having short tests, easy to understand and with a playful presentation that motivates the participant and facilitates the administration by the researcher. Likewise, it was found that the instrument is very useful for holistic evaluations, which not only identify the effect of malnutrition on cognitive processes such as memory and processing speed, but also take into consideration other sociodemographic variables that allow understanding people as biopsychosocial beings.

Finally, the pilot study made it possible to determine the variables that may influence the relationship between nutritional status and cognitive performance associated with episodic memory, working memory and processing speed in children between 6 and 10 years of age. The first of these is the mother's level of schooling, since it was observed that children with university-educated mothers had a better performance in the test associated with episodic memory, regardless of their nutritional status. Another variable that could have influenced the results is socioeconomic status, so it is recommended that this should be recorded in large-scale research. Finally, the time at which the children ingested the last meal prior to the assessment was also identified as a variable that should be controlled for, as it could have had an impact on the results.

It is hoped that these results will contribute to increase the body of knowledge that justifies how sensitive an environment that does not favor nutritional conditions, as well as the family and social environment in which a child grows up, can be for the development of cognitive

skills. This leads us to think that, as important as it is to control nutritional requirements, it is also indispensable to favor the environment in which our children develop.

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AUTHORS' CONTRIBUTION

The three coauthors of this article participated with the same degree of responsibility in the entire process of conducting this study, including the background review, its design, the execution of the pilot study, the statistical analysis of the data, and the writing of the manuscript. Victor Tortorici is listed as the corresponding author and leader of the research.

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