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Learning styles and academic performance: a correlational study among engineering university students

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ABSTRACT

In a context of little explanation of the links between learning styles (LS) and academic performance (AP) in university students, a quantitative analysis of these relationships was proposed in mechanical and electrical engineering students from a public university in Lima, Peru. The Honey-Alonso learning styles questionnaire (CHAEA) was used to identify the students' styles. Grades in various subjects were used as data on AP. Discriminant analysis and hierarchical clustering were applied to develop an explanatory model of the relationship. The findings revealed that most students were classified in a central level of AP. LS were distributed in order of relevance of contribution as: 'theoretical', 'reflective', 'active' and 'pragmatic'. The 'theoretical' and 'reflective' styles showed greater affinity. Better clustering was observed in the 'in process' and 'achievement' levels of AP. The level of 'starting' was diffuse among students, preventing it from being clearly associated with any LS, although it is recommended not to dismiss it because it may represent students who require additional support from teaching staff. This research contributes a holistic view of the factors that influence university AP and highlights the importance of conducting further research in this field.

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1. INTRODUCTION

Academic performance (AP) is an important indicator in the evaluation of education and is influenced by a wide range of variables [1]. On the other hand, learning styles (LS) have been investigated in relation to AP. LS comprise a set of cognitive, affective and physiological characteristics that define how individuals prefer to learn and process information [2], [3]. According to Mumford and Honey [3], LS are categorized into four main types: active, reflective, theoretical and pragmatic. Over the years, various researches have reported findings suggesting differences in students' AP based on their LS [4]. The incongruence between students' LS and the teaching methods used can lead to poor or suboptimal performance among students [5], [6]. Previous studies on the relationship between LS and AP have presented inconsistent results, some finding a significant and positive relationship [7], while others have found no correlation [8].

There is research that has found a positive correlation between LS and AP [9]–[12], suggesting that certain LS may be more effective for some students in certain contexts. In relation to engineering students, a study [5] determined that learning and teaching styles have a significant impact on students' AP. The study aimed to identify the LS of students enrolled in a programming technique course and analyze the relationship between LS and AP. The results indicated a significant relationship between the two, implying that aligning LS with appropriate teaching methods can improve AP.

On the other hand, other studies have not found a significant relationship between LS and AP [13], [14], indicating that the relationship may be more complex and influenced by other factors. For example, research by Al-Azawei *et al.* [15] examined the complex interrelationship between LS, gender, perceived satisfaction, and AP in four programming courses supported by an e-learning platform. The discrepancy in these findings suggests a gap in the literature that needs to be explored, and highlights the need to consider multiple variables when investigating the links between LS and AP.

In this context, the question was raised: what relationships do LS have with AP levels in university students? and what are the LS that best explain these levels of AP? In order to examine the relationship between LS and AP of undergraduate students from the Professional School of Mechanical and Electrical Engineering at the National Technological University of Lima South, a discriminant analysis was performed that aims to visualize more linked elements than what was provided by a correlational analysis. This research focused on a more specific and contextualized approach, which could provide more light on the particular dynamics of this population of students. Although some studies have identified significant relationships, there are many others that have not been able to establish such a relationship.

Precisely, one of the explanations for the variability of the relationship between LS and AP is due to the dynamism of the educational context, the disruptive incursion of commonly used technological tools after the COVID-19 pandemic, and the new learning approaches, [16], [17] reasons why it remains a topic of discussion today. Thus, for this research we sought to analyze the relationships between LS with respect to the AP of undergraduate students of the School of Mechanical and Electrical Engineering of the National Technological University of Lima South.

The literature is not conclusive regarding the explanation of the relationships between EA and RA, and weaknesses are noted in the proposal of indicators that can better explain this association, especially in an educational context that involves training designs that require technological assistance from information technology. Precisely, this research proposes a new vision of analysis, orienting it towards a determination of criteria that facilitate the classification of these in LS, but based on their AP and, encoding them in terms that allow a better understanding of this academic competence within a specific non-face-to-face, virtual university context. This need has become particularly urgent in response to contemporary educational challenges.

2. LITERATURE REVIEW

The Honey-Alonso learning styles questionnaire (CHAEA) was created by Peter Honey and Alan Mumford and later modified by Alonso-Martín *et al.* [18]. It consists of 80 questions that judge an individual's LS based on four categories: active, reflective, theoretical, and pragmatic [18]–[20]. Each category is assessed with 20 questions, and the results are interpreted based on the highest scores in each. Individuals with an active style (AS) learn through doing, whereas reflective learners learn by observing and reflecting on their experiences. Theorists learn by understanding fundamental principles and concepts, whereas pragmatists learn by implementing what they have learned in real-life situations [18]–[20]. It is important to note that LS are not mutually exclusive and an individual may exhibit characteristics of more than one style.

The Honey -Alonso questionnaire has been applied in numerous studies to determine LS in different groups, such as college students [19]–[21], nursing students [18], and mathematics students [22]. This questionnaire has also been used in long-term research to assess variations in LS over time [23]. In addition, the CHAEA has proven to be a useful tool for identifying learning preferences and helping educators adapt their teaching methods to meet students' learning needs.

The state of the art indicates a diversity of results classifying LS. Thus, there were reports where the theoretical and pragmatic style (PS) emerged as highly preferred, visualizing associations between active and reflective style (RS) [24] and, although there were similarities, other studies considered the PS inherent to students with the ability to discover new techniques linked to the curiosity to discover new methods in health sciences, testing them in the learning process [25]. For their part, Alonso-Martín *et al.* [18] analyzed the relationships between these styles, observing that the least preferred were the pragmatic, theoretical and AS, determining a direct relationship between these styles and the RS. What is interesting about this study is that it indicated the relevance of the continuous study of LS because these are dynamic in the academic training process, evolving over time. From this perspective, Jesús *et al.* [26] emphasized that LS should not be induced in students, but rather they should be taught study techniques so that they can adapt them to their

own style and develop new skills that allow them to adapt to training topics, as was also confirmed by Marin-Suarez and Alarcon [27].

From this perspective, Molina-Cabello *et al.* [28] tested a tool to analyze LS during the teaching process so that the teacher could make adjustments to his teaching processes, fine-tuning the content and strategies in accordance with the style detected in the student, also observing the evolution of the students. Another relevant aspect is that the use of these measurements early on would allow visualizing which professional career students would prefer from primary schools, since there is already evidence that some styles are linked to the choice of professional careers (PS) and with others of secondary education (reflective) [29].

3. RESEARCH METHOD

The research had a quantitative approach. There were 74 students belonging to the courses of mechanical drawing I, II, and strength of materials. It is important to highlight that the sample was composed of second, third and fifth cycle students of the School of Mechanical and Electrical Engineering of the National Technological University of Lima South and the selection strategy was conditioned to their willingness to participate in the study. That is, intentional sampling was used, which is justified by respect for the participants' decision to get involved in the research process, expressed in the signing of the informed consent before answering the questionnaires. It is indicated that initially, 79 people signed the informed consent, however, inconsistencies were detected in the responses of 5 participants (incomplete responses, strange response patterns, perfect response repetitions). For this reason, only 74 complete questionnaires were processed. The sample size is within the parameters of previous research [30].

For the variable LS, the data were collected using the Honey -Alonso questionnaire [31] applied in person during class sessions. The data were processed according to the instructions of this instrument. The marks obtained in each of the subjects evaluated constituted the data for the variable AP, which were classified as achievement, in process and, at the beginning [32]. Despite the instrument being the gold standard, a content validity process was carried out using the expert judgment technique. The average V-Aiken value obtained from the five validators for the questionnaire items was 0.870, which revealed a good reliability grade. Regarding the instrument’s reliability, a pilot sample of 22 students from another professional school was carried out, obtaining a Cronbach’s alpha value of 0.940, indicating high reliability. There were three probable confounding variables identified by the research team: sex, hours of internet use, and average hours of study. To reduce the effect of these variables, additional items were included that measured them. This led to analyzing the data in a segregated manner. However, no variability was identified in the results, compared to the global data analysis. The study focused on determining the association between LS and AP, using discriminant analysis, which allowed to segregate the modeled contribution of each of the LS to AP [21]. The results were expressed in terms of contribution coefficients to the AP of the students evaluated. Finally, a statistical test of hierarchical classification cluster was performed. This test was applied to visualize the distances between the LS with respect to AP and to explain the links between them.

4. RESULTS AND DISCUSSION

4.1. Results

In the cross-references between the variables AP and LS, it was evident that a significant number of students were classified correctly. However, a considerable number of students assessed were not. The interesting thing about this result is that the classification 'in the beginning' (of the variable AP) was paired with the 'high' level of most of the dimensions of the variable LS. The same was observed between the levels 'in progress' (also of the variable AP) and 'high' of the dimensions of the LS, which suggests levels of inverted dependence. In this context, the Chi^2 dependency test was carried out, with the aim of determining these links, observing that both for the AS, pragmatic and the same variable LS were significant to the test, revealing a dependency, although inverted for these factors with respect to AP, as seen in Table 1.

With the previous result it was necessary to determine which of the dimensions had the greatest impact on AP, as presented in Table 2. The discriminant analysis carried out determined two functions that explain this impact. Previously, the Wilks Lambda analysis revealed that this analysis is consistent with what is intended to be revealed. The value obtained (λ=0.498) indicates that the variable discriminates considerably, considering that the total variability observed is due to intergroup differences and not to those present within these data sets. Thus, in the structure matrix it was observed that the variable LS was more closely linked to function 1, being the one with the highest coefficient value, observing a correlation with the dimensions AS and pragmatic, while theoretical style (TS) had more association with function 2, which did not explain this style any more, and to a lesser extent with RS, considering that this function lacks the capacity to discriminate the dimensions that were analyzed.

In this context, the coefficients of the discriminant function in function 1 revealed that LS have greater importance than the rest of the dimensions, indicating that the classification will be positive towards the highest level of the AP classification (high level). Likewise, for both the active and theoretical styles, the contribution is not as significant, compared to the variable that groups these styles. On the other hand, the pragmatic and reflective styles classify students in the lower level of AP (low level). For function 2, only the active, theoretical and, to a lesser extent, the reflective styles allow the same students to be classified positively, while the LS variable and the PS did so antagonistically. For this reason, it is more coherent to adopt classification function 1, instead of function 2.

Table 1. Cross frequencies and results of the Chi test[2] between AP and the variable LS with its dimensions

Dimensions and variable	Levels	AP						Chi-square tests			
		Beginning		In progress		Achievement					
		n	%	n	%	n	%	Value	df	Asymp. Sig. (2-tailed)	N
AS	Low	4	5.7	11	15.7	0	0.0	18,692	4	0.001	70
	Half	19	27.1	8	11.4	9	12.9				
	High	12	17.1	2	2.9	5	7.1				
RS	Low	1	1.4	0	0.0	0	0.0	1,111	4	0.893	
	Half	4	5.7	3	4.3	2	2.9				
	High	30	42.9	18	25.7	12	17.1				
TS	Low	0	0.0	0	0.0	0	0.0	0.128	2	0.938	
	Half	4	5.7	3	4.3	2	2.9				
	High	31	44.3	18	25.7	12	17.1				
PS	Low	1	1.4	3	4.3	0	0.0	11,944	4	0.018	
	Half	11	15.7	11	15.7	2	2.9				
	High	23	32.9	7	10.0	12	17.1				
LS	Low	1	1.4	0	0.0	0	0.0	35,477	4	0.000	
	Half	9	12.9	19	27.1	0	0.0				
	High	25	35.7	2	2.9	14	20.0				

Table 2. Discriminant functions of the structure matrix and standardized canonical discriminant function coefficients for the variable AP having as predictor the variable LS with its dimensions

Factors	Matrix of structures		Standardized canonical discriminant function coefficients	
	Function		Function	
	1	2	1	2
LS	0.856*	0.057	1.136	-0.545
AS	0.549*	0.483	0.138	0.940
PS	0.434*	-0.026	-0.118	-0.137
TS	0.014	0.539*	0.005	0.841
RS	-0.004	0.251*	-0.549	0.479

Test of functions 1 to 2: Wilks' Lambda=0.498; Chi^2=42.495; gl=10; Sig=0.00<0.05.
Function 2: Wilks Lambda=0.970; Chi^2=1.888; gl=4; 0.756>0.05.
Pooled within-group correlations between variables and standardized canonical discriminant functions.
Variables ordered by the absolute size of the correlation within the function.
*. The highest absolute correlation between each variable and any discriminant function.

On the other hand, the calculation of the coefficients of the classification function allowed to distinguish the independent contribution of each of the LS for the conditions of AP, as shown in Table 3. Thus, it was observed that it was the TS that had the greatest contribution in the three conditions of AP, also observing that the highest absolute value of the constant was seen in the 'At the beginning' condition of this variable. On the other hand, for the integration of the model, it is relevant to highlight that the ideal condition is achievement, for which the equation could be developed with the combined contributions of each style (1), however, considering that the largest number of students were located in the 'In process' level, a model (2) is also proposed considering that the value of the constant was the lowest obtained from the three proposed levels. The modeling of this proposal is linked to the result of the clusters of the discriminant classification product of the interaction of the only two resulting functions in the previous analysis, observing that the levels of AP that presented the best grouping were 'achievement' and 'in process' that had a greater amount of data grouped close to their group centroids. In contrast to the level 'in beginning' that presented a lot of dispersion with respect to its centroid, indicating that the modeling of this condition of AP would not necessarily be linked to the learning style, which would give space to a deeper analysis in this regard in future research, as shown in Figure 1.

Table 3. Fisher classification function coefficients for the levels of AP based on the LS of university students

LS	AP		
	Beginning	In progress	Achievement
AS	8.661	7.941	8.200
RS	17.344	19.392	15.566
TS	31.121	30.474	30.006
PS	0.920	1.324	0.844
(Constant)	-82.133	-75.440	-81.173

Fisher linear discriminant functions

The proposed models are in (1) and (2):

$$Academic\ performance_{[Achievement]} = -81.17 + 8.20EA + 15.57ER + 30.01ET + 0.84EP \quad (1)$$

$$Academic\ performance_{[In\ progress]} = -75.44 + 7.94EA + 19.39ER + 30.47ET + 1.32EP \quad (2)$$

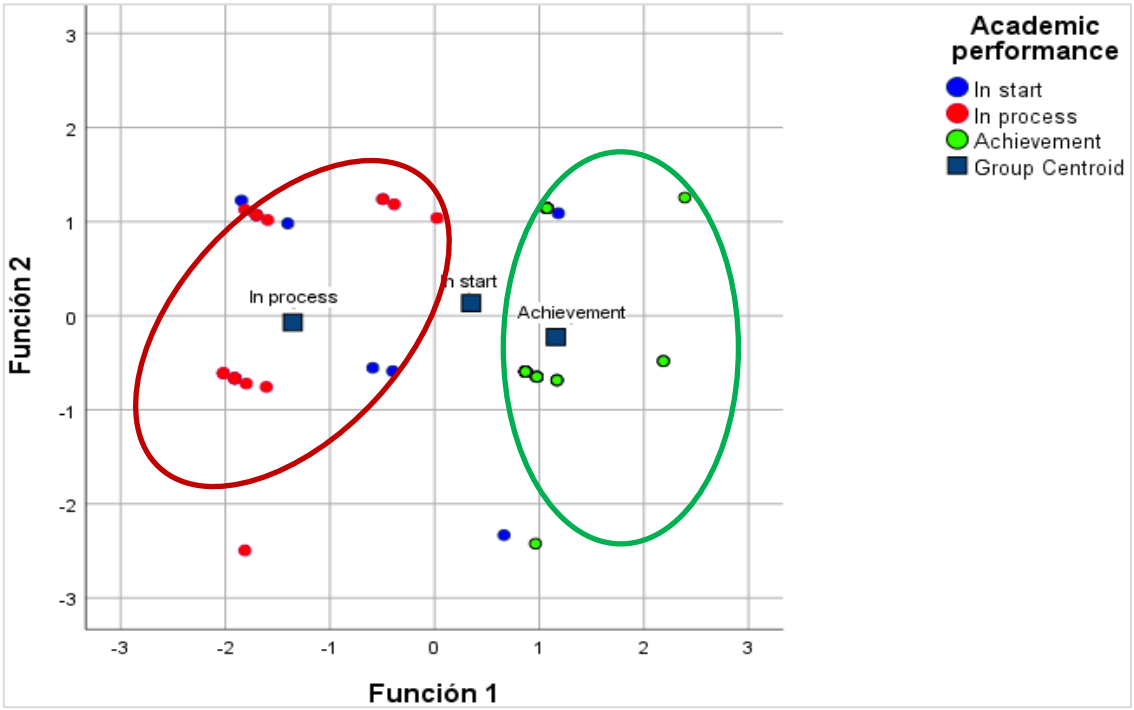

Figure 1. Canonical discriminant functions for grouping the levels of AP of the university students evaluated

Finally, with the sole purpose of providing the closest approximation between the LS that determine the AP of these evaluated students, a hierarchical classification dendrogram was created using agglomerative methods (clusters) by means of Euclidean distances, observing that the smallest distance was between the reflective style (Reflective_S) and the theoretical style (Theoretical_S), as shown in Figure 2. It formed a first cluster, being consistent with the classification of the discriminant analysis visualized in the Fisher classification function coefficients, as shown in Table 3, where the highest values were observed in these two LS. In that order of classification, the pragmatic style (Pragmatic_S) was the next style that came closest to the first two. The active style (Active_S) was seen to be much further away. From this it follows that it would be a good strategy to strengthen the reflective and theoretical styles to improve the level of AP in this group of students.

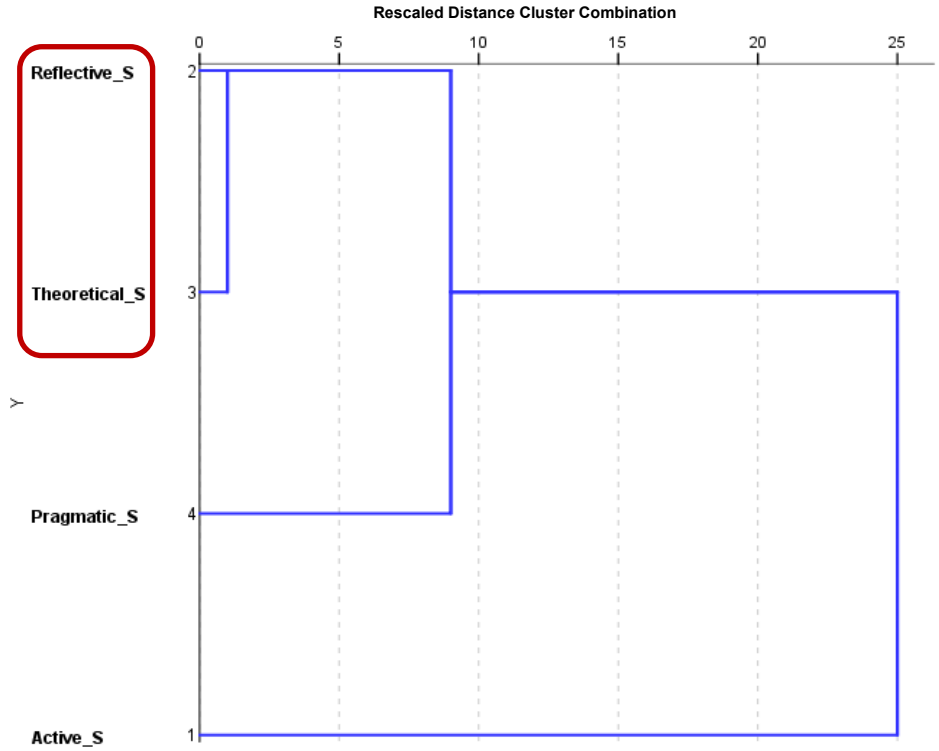

Figure 2. Hierarchical classification dendrogram of the LS of the students evaluated
*Euclidean distances have been used using average links between groups

4.2. Discussion

The literature reports a significant number of investigations that sought to determine relationships between the two variables analyzed [13]–[15]; however, the proposal of this study is to provide other analysis options that allow visualizing the contributions of each of the styles to AP, as previously proposed by other researchers [33], [34]. This type of analysis opens the possibility of delving into other methods that would better clarify the links and explain atypical student behavior [35], [36], considering that technological tools provide a greater diversity of options for learning, especially after the pandemic where their use became widespread. Currently, they are a constituent part of the university educational ecosystem.

Regarding AP, it was reported that it is in an intermediate category, although the trend was negative, a situation that is consistent with the observed reality. However, the questioning should not be linked only to the results obtained, which, in evolutionary terms, could be attributed to a hybrid training (remote-face-to-face) that could condition learning [37]. Thus, probably justify these insufficient levels of AP for the professional training stages, but should also question the evaluation system prevailing in the country [38], taking on the challenge of designing new modalities of evaluation of competencies without resorting to the traditional memorization methods that prevail in the education of engineering students.

These findings call into question the notion that a specific LS can directly influence AP. It is crucial to keep in mind that there are other elements and variables that can impact students' AP and that could be the target of future research. At this time, it is important to start the discussion from the relevance of the LS as a direct cause of performance. Perhaps it is time to talk about the combination of styles and group them with new nomenclatures [2], since the literature provides evidence of the ineffectiveness of the induction of styles for learning but rather emphasizes the importance of using tools that would facilitate meaningful learning in students [18], [26], a recommendation that could open a new panorama of university curricular restructuring.

Arguing the results, the AP of university students is affected by several factors that are not only linked to LS. These include academic and social integration, perceived academic control, self-image, leadership styles, personality traits [39], social, economic and academic factors [40], institutional factors, psychosocial factors, and life satisfaction and self-esteem [15], [41]–[43]. Likewise, it has been shown that academic and social integration are key determinants in the success and permanence of university students [44]. Although these cannot directly predict the grade point average, they do predict the intention to persist, which indicates their influence on AP. Understanding these factors is important to support the success and persistence of students in higher education.

It has been shown that perceived academic control has a stronger impact on students' grade point averages than the predisposition to critical thinking [45]. This suggests that students' beliefs about their control over academic outcomes play a crucial role in their AP and leaves open the possibility that it can be modulated by employing strategies that accompany didactics in the process of academic interaction. Thus, emphasizing the understanding of self-concept could be a good starting point, due to the evidence as a mediator between resilience and AP [46], having it as a basis for analyzing their personality traits as a lever that strengthens AP [40]. However, this would imply that teachers should be trained in handling procedures and/or strategies that go beyond didactics and explore the terrain of psychopedagogy.

Although not directly linked, it is necessary to mention that, from an organizational perspective, universities constitute units where the actions of officials and authorities determine the academic learning models of their students, having scientific evidence to assert that leadership styles and organizational culture also affect the performance of teachers within these entities [47]. Therefore, if changes are proposed that are oriented towards improving student AP, it is essential to involve organizational culture as a fundamental part of the change. Of course, important processes and recommendations to follow are provided from the academy, however, these should be analyzed in specific studies later.

5. CONCLUSION

In conclusion, the findings revealed that the majority of students were classified as being in a central level of AP ('In progress'), although the tendency was towards the lowest level ('initiation'). Regarding LS, 'reflective', 'theoretical' and 'pragmatic' showed levels of 'high' with a tendency towards 'medium'. Only the 'active' style showed a high proportion at the 'medium' level with a tendency towards the 'high' level. This revealed that LS are not clearly defined in this group of students, being somewhere between the 'medium' and 'high' levels. On the other hand, the AP of the students was mostly classified as being in the 'low level' for the 'pragmatic' and 'reflective' LS. The 'theoretical' style was the one that had the greatest contribution to the classification coefficients for the three levels of students' AP, although it was much greater in the lower condition ('initiation' performance). In this way, in order of relevance of contribution, the styles were distributed as: 'theoretical', 'reflective', 'active' and 'pragmatic', which was the one that contributed the least to AP. Finally, in general terms, the 'theoretical' and 'reflective' LS were shown to be more similar in the results of these students, showing a better grouping of both the 'in process' and 'achievement' levels for AP. The 'starting' level of performance was very diffuse among the students evaluated, which did not allow it to be reliably associated with any LS; however, it is recommended that it should not be dismissed because it constitutes an important group of students who, most likely, require additional support from the assigned teaching staff.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

INFORMED CONSENT

The authors declare that the study did not involve human participants.

ETHICAL APPROVAL

The authors declare that the study did not involve human or animal participants.

DATA AVAILABILITY

The data supporting the findings of this study are available upon request from the corresponding author [JASA].

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