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Exploring JASP as a data analysis tool in L2 research: a snapshot

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Abstract: This paper explores the potential of JASP (Jeffreys's Amazing Statistics Program, https://jasp-stats.org/) as a robust statistical tool in advancing Second Language Acquisition (SLA) research, with a specific emphasis on its application within the domain of L2 writing. Second language writing proficiency is a complex and multifaceted skill, demanding rigorous empirical investigation to uncover nuanced patterns and insights. JASP, known for its user-friendly interface and advanced statistical capabilities, emerges as a promising instrument for researchers seeking to unravel the intricacies of L2 writing development. The paper begins by providing an overview of the features embedded in JASP and continues to discuss some of the extant research within the field of SLA that implements JASP as a data analysis tool. Follows is a detailed description of the use of JASP in two L2 writing papers, in which the data analysis decisions are discussed. Furthermore, the discussion delves into the practical implications of utilizing JASP in L2 writing research, including its ability to accommodate small sample sizes, handle complex interactions, and facilitate transparent and reproducible analyses. The paper concludes by advocating for the widespread adoption of JASP in SLA research, positing that its integration holds the promise of advancing our understanding of the intricacies of L2 writing development and contributing to the refinement of pedagogical approaches in second language education.

Keywords: second language acquisition research; L2 writing; data analysis

Català:

Perspectives de l'ús de JASP com a eina d'anàlisi de dades en la recerca sobre L2

***Resum**: Aquest article explora el potencial de JASP (Jeffreys's Amazing Statistics Program, https://jasp-stats.org/) com a eina estadística robusta per avançar en la recerca sobre l'Adquisició de Segones Llengües (ASL), amb un èmfasi específic en la seva aplicació en el domini de l'escriptura de L2. El domini de l'escriptura en una segona llengua és una habilitat complexa i polifacètica que exigeix una investigació empírica rigorosa per descobrir perspectives i patrons matisats. JASP, conegut per la seva interfície fàcil d'usar i les seves capacitats estadístiques avançades, es perfila com un instrument prometedor per als investigadors que busquen desentranyar els secrets del desenvolupament de l'escriptura en L2. L'article comença proporcionant una visió general de les característiques incorporades a JASP i continua discutint algunes de les investigacions existents al camp d'ASL que implementa JASP com una eina d'anàlisi de dades. A continuació, s'ofereix una descripció detallada de l'ús de JASP a dos treballs d'escriptura de L2, en què es discuteixen les decisions d'anàlisi de dades. A més, la discussió aprofundeix en les implicacions pràctiques de la utilització de JASP en la investigació de l'escriptura en L2, incloent-hi la capacitat per acomodar mostres de mida petita, manejar interaccions complexes i facilitar anàlisis transparents i reproduïbles. L'article conclou advocant per l'adopció generalitzada de JASP en la recerca de SLA, alhora que postula que la seva integració promet avançar en la comprensió de les complexitats del desenvolupament de l'escriptura en L2 i contribuir al perfeccionament dels enfocaments pedagògics en l'ensenyament de segones llengües.*

***Paraules clau**: recerca en l'adquisició de segones llengües; escriptura en L2; anàlisi de dades*

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Español:

Perspectivas del uso de JASP como herramienta de análisis de datos en la investigación de L2

***Resumen**: Este artículo explora el potencial de JASP (Jeffreys's Amazing Statistics Program, https://jasp-stats.org/) como herramienta estadística robusta para avanzar en la investigación sobre la Adquisición de Segundas Lenguas (ASL), con un énfasis específico en su aplicación dentro del dominio de la escritura en L2. El dominio de la escritura en una segunda lengua es una habilidad compleja y polifacética, que exige una investigación empírica rigurosa para descubrir patrones y perspectivas matizados. JASP, conocido por su interfaz fácil de usar y sus avanzadas capacidades estadísticas, se perfila como un instrumento prometedor para los investigadores que buscan desentrañar los entresijos del desarrollo de la escritura en L2. El artículo comienza proporcionando una visión general de las características incorporadas en JASP y continúa discutiendo algunas de las investigaciones existentes en el campo de ASL que implementa JASP como una herramienta de análisis de datos. A continuación, se ofrece una descripción detallada del uso de JASP en dos trabajos de escritura de L2, en los que se discuten las decisiones de análisis de datos. Además, la discusión profundiza en las implicaciones prácticas de la utilización de JASP en la investigación de la escritura en L2, incluyendo su capacidad para acomodar muestras de pequeño tamaño, manejar interacciones complejas y facilitar análisis transparentes y reproducibles. El artículo concluye abogando por la adopción generalizada de JASP en la investigación de SLA, al tiempo que postula que su integración promete avanzar en nuestra comprensión de las complejidades del desarrollo de la escritura en L2 y contribuir al perfeccionamiento de los enfoques pedagógicos en la enseñanza de segundas lenguas.*

***Palabras clave**: investigación sobre la adquisición de segundas lenguas; escritura en L2; análisis de datos*

1. Introduction: Analyzing data in L2 Research

The acquisition of a second language (L2) is a complex process that involves the development of skills in understanding, speaking, reading, and writing in a language other than one's native tongue. L2 learning is not only an academic pursuit but also a vital component of global communication, cultural exchange, and economic activity. In an increasingly interconnected world, proficiency in multiple languages is a valuable asset that can enhance cognitive abilities, cultural understanding, and open doors to international opportunities (Bialystok, 2017). Given this vital significance, the processes involved in second language acquisition (SLA) have been a focal point of research in the field of Applied Linguistics since its origins in the 60s and 70s (Ellis, 2021) and studies have implemented a whole range of research methods, generating an array of data sets to answer the questions concerning L2 learning (Mackey & Gass, 2015). These data sets have been analyzed from both quantitative and qualitative perspectives and as research progressed, so did the ways in which the data was viewed, including for example, mixed-methods studies (Hashemi & Babaji, 2013). Alongside the development of research methods, comes the progression of data analysis and the need for robust statistical analysis tools. As a result, SLA research has seen a rise in the use of numerous data analysis programmes such as SPSS (https://www.ibm.com/es-es/products/spss-statistics), R-Studio (https://posit.co/download/rstudio-desktop/) and, more recently, JASP (https://jasp-stats.org/).

1.1 Statistical analysis in studying L2 learning phenomena

Statistical analysis plays a crucial role in L2 research, as it provides a means to systematically investigate the intricacies of language acquisition. Through statistical methods, researchers are able to analyze data to uncover patterns, test theories, and draw evidence-based conclusions about language learning processes (Larson-Hall, 2016). The use of statistical tools enables the examination of variables such as exposure, instruction, and individual differences (e.g., age,

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L2 proficiency, etc.), which are all pertinent to understanding the dynamics of L2 learning. However, despite the crucial role statistical analysis plays in SLA research, it is not uncommon knowledge that many researchers in the field of L2 learning lack training and therefore, advanced knowledge in statistics and in using the existent interfaces to carry out data analysis tests (Crowther *et al.*, 2020; Loewen *et al.*, 2020).

In order to respond to this obstacle, many researchers have published guides on how to successfully carry out statistical analysis in the field of Applied Linguistics and more specifically, in the field of SLA (see Garcés-Manzanera, 2022; Larson-Hall & Herrington, 2010; Larson-Hall, 2016; Loerts *et al.*, 2020; Roever & Phakiti, 2018). Earlier publications focused on the use of SPSS, a commonly used data analysis tool amongst researchers within the field. However, given that SPSS is not a free open-access tool, authors began to design data analysis guides using tools that were freely accessible to everyone, such as R-Studio and JASP. As opposed to R-Studio which can be quite an intricate tool for SLA researchers, given its use of coding as the primary language, JASP offered researchers with a user-friendly interface, particularly helpful for young career researchers beginning in the field., whilst at the same time offering the possibility of more advanced statistical analyses, such as Bayesian methods, for more experienced scholars.

1.2 Introduction to JASP as a free and open-source statistical software

JASP (*Jeffreys's Amazing Statistics Program*, https://jasp-stats.org/) is a free and open-source statistical software program supported by the University of Amsterdam. It is designed with ease of use in mind, making it accessible to those familiar with programs like SPSS. Its user-friendly interface and extensive graphical capabilities significantly contribute to its popularity in both educational and research settings.

Figure 1

Descriptive Statistics in JASP

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JASP offers both classical and Bayesian analysis procedures, producing results in APA style to facilitate publication within many research fields. Particularly notable is the possibility mentioned of carrying out Bayesian statistical methods, which provide a robust alternative to traditional frequentist approaches (Pfadt, 2022). This framework is pivotal for researchers who wish to seek to incorporate prior knowledge into their analysis, providing a more nuanced and context-rich interpretation of data, which can prove essential in understanding complex language learning processes.

Recent advancements in JASP have expanded its utility, particularly in terms of Bayesian analysis. Tutorials have been developed to guide users in applying Bayesian methods to specific statistical tests, such as single-test reliability analysis (Pfadt, 2022), tests of two proportions (Hoffmann *et al.*, 2022), and Bayesian model-averaged meta-analysis (Berkhout *et al.*, 2023). These resources are invaluable for those new to Bayesian methods, offering clear, step-by-step guidance, in a user-friendly software such as JASP.

Additionally, JASP also promotes open science through its integration with the Open Science Framework which aims at ensuring reproducibility and promoting transparency by embedding analysis settings into the results (JASP Team, 2023). The educational potential of JASP is further underscored by its application in diverse fields. This versatility demonstrates JASP's adaptability and relevance across various academic disciplines.

1.3 JASP as a data analysis tool: advantages and limitations

JASP stands out in the realm of statistical analysis due to its free and open-source nature, which democratizes access to advanced statistical tools. Unlike proprietary software like SPSS, JASP is accessible to all researchers, which is particularly beneficial for those in underfunded institutions or countries. Its user-friendly interface is designed to be intuitive for users familiar with other statistical packages, thereby lowering the barrier to entry for conducting sophisticated analyses (Kelter, 2020).

One of the significant advantages of JASP is its integration of both frequentist and Bayesian statistical methods, both described in more detail below. This dual capability allows researchers to not only test hypotheses but also to incorporate prior knowledge and beliefs into their analyses, providing a more nuanced understanding of L2 learning phenomena (Quintana & Williams, 2018). However, one limitation of JASP is that, being a newer software, it may not yet have the same breadth of advanced features or the extensive user community that more established programs like SPSS or R have. Notwithstanding, over time, it will likely begin to gain more attention as an alternative data analysis tool.

Another advantage is JASP's commitment to open science. It encourages transparency and reproducibility by allowing researchers to share their data and analysis procedures directly through the software. This feature is particularly relevant in the context of L2 learning research, where reproducibility is crucial for validating findings across diverse linguistic and cultural contexts.

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Despite these strengths, JASP's limitations include a smaller range of available statistical tests compared to more mature statistical packages. Additionally, while JASP is improving its documentation and online resources, the support available may not be as extensive as that for other tools, potentially leading to a steeper learning curve for some of the more complex analyses (Brydges & Gaeta, 2019), something which we believe will be overcome throughout the following years, given its ever-increasing popularity within the field of L2 research.

In general, the adoption of JASP within the academic community has been steadily increasing, as evidenced by its use in a variety of research fields, including L2 learning. Its impact is particularly notable in promoting the principles of open science and reproducible research. By providing a platform that is both accessible and capable of sophisticated analyses, JASP is lowering the barriers to conducting high-quality statistical research (JASP Team, 2023).

The impact of JASP is also evident in the way it has facilitated a shift towards Bayesian statistical methods in the social sciences. As previously mentioned, Bayesian methods offer a different perspective on data analysis, one that is increasingly being recognized for its ability to handle complex models and incorporate prior information. JASP has been instrumental in this shift by providing tools that make Bayesian methods more accessible to researchers who may not have a strong background in statistics (Wagenmakers *et al.*, 2018) and has contributed to a higher use of these methods within the field of second language research, as detailed in the following section.

2. JASP in L2 research

JASP is particularly relevant for L2 learning research due to its comprehensive range of statistical tests, which are pertinent for analyzing language learning data. It includes tests for ANOVA, ANCOVA, repeated measures ANOVA, and MANOVA, among others, which are commonly used in L2 research to assess the impact of different instructional methods and learning conditions on language acquisition outcomes (Plonsky, 2013; 2014).

Developed at the University of Amsterdam, JASP has been financially supported by several universities and research funds, reflecting its credibility and the trust the academic community places in it (JASP Team, 2023). As mentioned above, its design facilitates the application of both frequentist and Bayesian inference, allowing for a more nuanced understanding of L2 learning phenomena. Bayesian inference, in particular, is valuable in L2 research for its ability to incorporate prior knowledge into the analysis, providing a richer context for interpreting results (Quintana & Williams, 2018).

JASP's applicability in L2 learning research extends beyond its comprehensive range of statistical tests. It plays a crucial role in analyzing language learning data, especially in studies focusing on the effectiveness of different instructional methods and learning conditions (Wagenmakers *et al.*, 2018). Its robust capabilities in ANOVA, ANCOVA, repeated measures ANOVA, and MANOVA are particularly useful for such assessments.

JASP was developed to be a more accessible and open alternative to proprietary statistical software, and its application in L2 research is growing. It has been used to analyze data in studies examining a range of diverse variables,

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including speech fluency (Chau *et al.*, 2022), L2 writing (Mazgutova & McCray, 2023), L2 motivation (Zalbidea *et al.*, 2022), and digital game-based language learning (Dixon *et al.*, 2022) to mention a few. Follows is a summary of how some of this research within the field of SLA which has implemented JASP as a data analysis tool.

The integration of JASP in second language (L2) learning research has been a progressive step towards more transparent and accessible statistical analysis. Kelter (2020) highlights the seamless transition researchers can make from traditional statistical packages like SPSS to JASP, thanks to its aforementioned user-friendly, point-and-click interface. Given the ease JASP presents for researchers, SLA research has seen an increase in its implementation. However, despite some researchers referencing the statistical package they have used for their study, it remains an uncommon practice within the field. That is, many researchers fail to detail the software used and when carrying out the literature review on JASP in L2 learning research for the current paper, it became apparent that this is an issue throughout the field. Notwithstanding, there are a number of research papers that include essential information on the software used and how they implemented it.

As JASP provides the opportunity for carrying out Bayesian analysis, Chau *et al.* (2022) carried out five Bayesian repeated measure ANOVAs using JASP. This decision was made "in order to attend to the inference crisis of the social and behavioral sciences", by providing additional information via Bayesian methods, to complement the testing that relies on *p*-values. The values in their research were interpreted according to Norouzian *et al.*'s (2019) Classificatory Scale. The data analysis provided by JASP proved to be decisive in demonstrating that pronunciation instruction did not play a role on speed fluency improvement for the participants under study (11 native English speakers from the USA).

In line with the research mentioned (Chau *et al.*, 2022), Zalbidea *et al.* (2023) also implemented Bayesian analysis using the *EBICglasso* procedure in JASP. Zalbidea *et al.* (2023) detail the procedures followed and even include specific footnotes on the data analysis potential JASP has for providing information on nodes. The extensive detail provided on the implementation of JASP is uncommon in SLA research and the study by Zalbidea *et al.* (2023) is one of the very few that includes such rich particulars. JASP was used in this study specifically for examining heritage language (HL) learners' motivational profiles, by modelling the data "into an exploratory regularized partial correlation network" (p. 989). The advanced data analysis carried out in this study was able to shed light on psychological network modeling within the specific domain of HL learning motivation, revealing positive connections between the variables analyzed and the HL learners, including intended effort, enjoyment and HL selves.

In line with the research included in this paper, Mazgutova and McCray (2023) also use Bayesian methods via JASP to explore revision behavior in L2 writing. Their research collected data via keystroke logging and explored the changes over a one-month period of students writing in an English for academic purposes (EAP) programme. The data collected (L2 written products and keystroke logging evidence) was analysed and their interpretation were based on Norouzian *et al.* (2019) and Wagenmakers *et al.* (2018)'s Bayesian method explanations, which envision the results

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according to Bayes factor hypothesis testing (BHT) - which will be explained in later sections - which is based on a *Cauchy* value of 0.707. The results from the BHT analysis showed evidence of no difference in terms of the student's engagement with text revisions from Time 1 to Time 2 and the authors explicitly claim that thanks to the BHT method implemented via the use of JASP, they were able to provide a more detailed explanation of the results, especially when compared to more frequentist methods. In addition, they add that the BHT analysis demonstrated that their study, with the specific conditions included, would not likely show different results if replicated in the future and thus, the authors recommend that any future research looking into L2 text revisions over time should include a variety of different variables.

Other research within the field which has used JASP as the data analysis tool has focused on more frequentist models and the inclusion of effect sizes. Dixon *et al*. (2022) investigated the effectiveness of digital based language learning (DGBLL) by carrying out a meta-analysis on the research that has been carried out on digital games in L2 learning contexts. Their analysis was based on within-group and between-group designs and following Plonksy & Oswald (2014), they selected Cohen's *d* as the effects size measurement, and followed the benchmarks established. The authors provide a very thorough description of the data analysis procedure and go into detail regarding the effect sizes and models in question. In terms of the results and the data output provided by JASP, forest plots were created to illustrate the individual effect sizes for each of the studies included in the meta-analysis, as well as to illustrate between and within-group effects. These plots allow the authors to provide visual support for their results which conclude that DGBLL appears to effectively contribute to language learning, especially when compared to non DGBLL instruction.

In conclusion, JASP's role in L2 learning research is multifaceted. It serves as a bridge between traditional statistical methods and modern, open-science practices. Its growing adoption and therefore, its impact reflect a broader movement in the academic community towards more transparent, accessible, and sophisticated statistical analysis. Owing to its significance thus far within the field of SLA and the opportunities it presents as a reliable and powerful data analysis tool, this study aims to offer a comprehensive description of JASP's utility in L2 research from two distinct perspectives: more traditional frequentist methods in Study 1, and Bayesian methods in Study 2.

3. An empirical evaluation of JASP in our research practice

3.1 Study 1: Using frequentist methods in L2 research

Introduction and objectives of the research

The first study described in this paper corresponds to an unpublished doctoral thesis which was carried out in order to respond to two SLA-oriented lines of research. On the one hand, it examined the effects of writing medium on the L2 written accuracy of texts. That is, the research focused on the effect of computer mediated writing versus traditional

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pen-and-paper writing. On the other hand, the thesis aimed at exploring the effects of three different feedback processing conditions (think-aloud protocols; written languaging; and simultaneous think-aloud protocols with written languaging) on the student's engagement with the feedback and subsequent written production. As the main contribution of the study was empirical, the data collected was analyzed in order to provide empirical evidence on the phenomenon under study.

Methodology and participants

The study followed a pre-test/treatment/post-test design in which a total of thirty-six undergraduate students participated. The students belonged to the fourth year of an English philology degree and were all enrolled on a course on Applied Linguistics. Participants were first invited to complete an Oxford Placement Test (OPT) in order to confirm L2 proficiency homogeneity, which corresponded to an intermediate/high-intermediate level of B2-C1 proficiency (according to the Common European Framework of Reference for Languages). Once they had completed the OPT, they were asked to write an initial text (pre-test) in a 50-minute time-constrained condition. The writing task was the "Fire Chief" task (Gilabert, 2007) which consists in a problem-solving, picture-based task in which students are presented with a drawing of a burning building with a number of people inside, the students are required to detail how they would save the people inside the building, in which order, and justify why. The writing tasks were corrected with direct written corrective feedback (WCF) and given back to the students in order for them to process the error corrections that had been provided.

For the processing stage of the study, participants were divided into three groups according to the manner in which they were asked to process their WCF. Therefore, the first group were asked to think aloud and verbalize their thoughts on the errors and their corrections. The second group were asked to complete a written languaging table and provide relevant information about the errors and their corrections. Finally, the third group were asked to do both of these processing tasks simultaneously. That is, they were asked to complete the written languaging table whilst also verbalizing their thoughts out loud (think-aloud protocols). The final task (post-test) asked participants to return and rewrite their original texts under the exact same conditions as in the pre-test.

Choosing the right statistical approach: why frequentist?

Given the nature of the study, which focused heavily on exploring the effects of written corrective feedback processing on both the levels of depth of processing of the participants, as well as on their L2 written production, decisions had to be made on the data analysis procedures to optimize the wide range of data the research expended. One main criterion which had to be taken into consideration was the small sample size included in the study. As previously mentioned, there were 36 participants included in the research. However, these students were divided into two primary experimental groups; computer-mediated writing and pen-and-paper writing, therefore leaving a small sample of 18

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participants per writing condition. In addition, each writing condition processed the feedback provided according to the three feedback processing conditions previously mentioned and thus, the groups were reduced to 6 students per feedback processing condition. Added to the reduced sample size, much of the data collected was qualitative in nature, particularly the think-aloud protocol data and thus, a mixed method approach was essential in order to truly explore the data from each experimental condition in an optimal manner. Given the small sample and the number of variables included within the study, the decision was made to calculate descriptives, including means, standard deviations and 95% CIs, as well as calculating *d* values (effect sizes) using JASP for the L2 written production, and frequency counts were calculated for the written corrective feedback processing levels across the various conditions.

Analysing the data with JASP

The data collected consisted of the written texts produced in the pre- and post-test, as well as the WCF processing data. Once all data had been collected, the written texts were analyzed in terms of their complexity, accuracy and fluency (CAF) by using manual calculations for accuracy (number of errors/total number of words *100) and fluency (total number of words/total time spent on task) and the online SYNLEX tool (https://aihaiyang.com/software/lca/) for complexity (Ai & Lu, 2010; Lu, 2012).

In terms of the WCF processing data, the think-aloud protocols were transcribed and coded following Leow's (2015) definition of depth of processing (DoP), and the written languaging data was coded according to levels of noticing and engagement, guided by a coding scheme created by Cerezo *et al*. (2019). For a detailed explanation of the data coding scheme elaborated for the study, see McBride and Manchón (2023).

In terms of data analysis, within-groups analyses were performed on the quantitative data in order to explore the results in terms of the written corrective feedback processing conditions. In addition, between-groups analyses were performed in order to explore the effects of digital versus pen-and-paper writing environments. Given that the number of participants was relatively low, and the thesis included a wide range of variables (WCF processing instruments and two writing conditions), the decision was made to include descriptive measures which were calculated using JASP 0.14.1. In order to carry out the analysis, first the means and standard deviations were calculated for the L2 written CAF measures (as shown in Figure 2).

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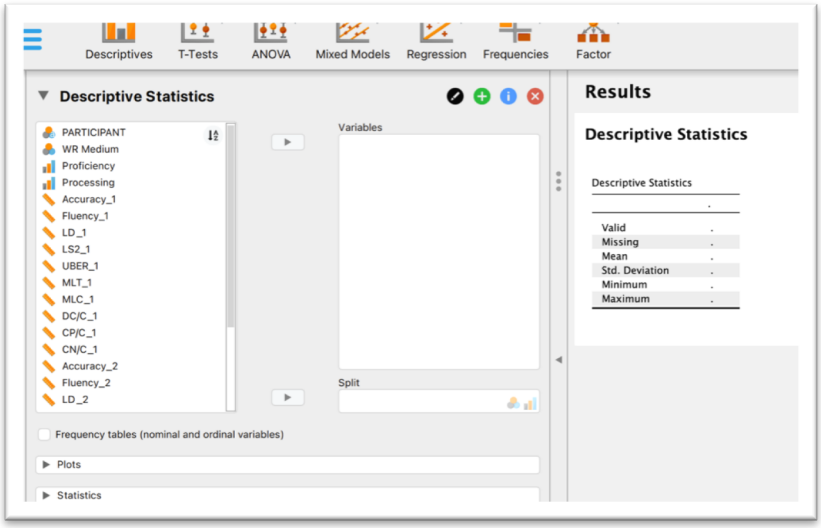
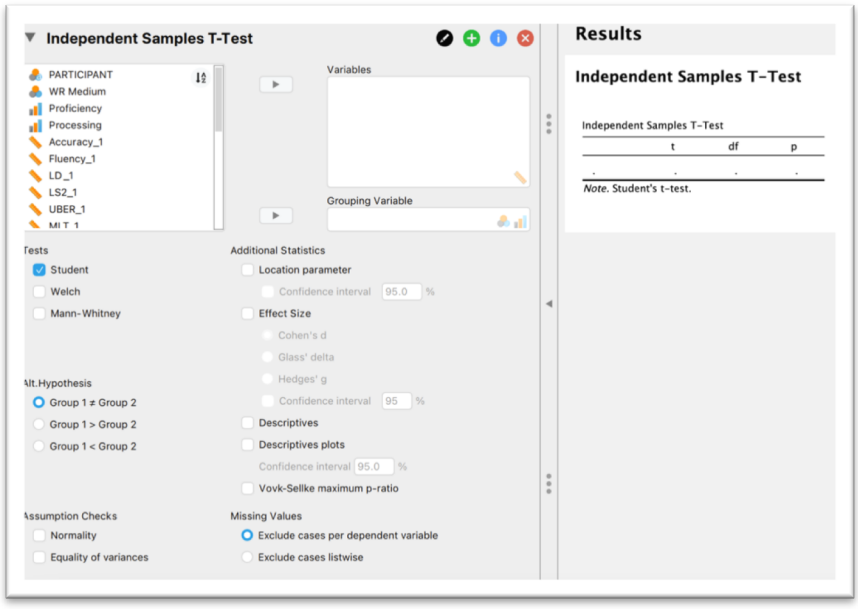
Figure 2
Descriptive Statistics in JASP



Once we had analysed the data in terms of descriptive statistics, we were then able to carry out independent samples t-tests, and paired sample t-tests in order to compare the means of the various variables under study which included the effects of writing medium (digital vs pen-and-paper) on the L2 written production of the participants (CAF measures), as well as the effects of the WCF processing conditions (think-aloud, written languaging, and simultaneous think-aloud and written languaging) on L2 written products (CAF measures).

Figure 3
Independent Samples T-Test in JASP



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In addition, and in order to understand the magnitude of the differences found between the variables analyzed, Cohen's *d* effect sizes were also calculated (an option available within JASP, as shown in Figure 3. Following previous research (Plonsky *et al*., 2021), the effect sizes were interpreted according to the parameters summarized in Table 1 below:

Table 1
Benchmarks for SLA Research Effect Sizes (Plonsky et al.*, 2021)*

Effect Size	Small	Medium	Large
Between-groups	0.40	0.70	1.00
Within-groups	0.60	1.00	1.40

The inclusion of effect sizes in the study was motivated by the growing importance of this parameter in SLA research in recent years. Furthermore, given the relatively small sample size and the multitude of variables incorporated in the research design, effect sizes proved to be a valuable tool for producing a robust and dependable interpretation.

Reflections on using JASP for frequentist methods

The output provided by JASP allowed us to provide a solid analysis of the data collected, facilitated by the easily interpretable results this data analysis tool provides. The results are presented in a way that helps users understand the statistical findings, including effect sizes (as in the study carried out), and any other relevant information required. By first examining the descriptive statistics of the variables of interest (writing medium and WCF processing), we were able to obtain an initial sense of the central tendencies and variability in the data. Then, according to the research questions established, we were able to employ the independent samples t-Test, and paired sample t-Tests to assess the significance and practical importance of the results obtained. The effect sizes were essential in obtaining the practical importance of the results as they provided information on the magnitude of the observed effects found in each t-Test carried out. Given that the data belongs to an unpublished doctoral thesis, this paper will not go into any further detail on the specific results found.

3.2 Study 2: Using Bayesian statistics in L2 research

Introduction and objectives of the research

The study involved a group of 55 undergraduate students, who participated in a questionnaire developed specifically for this research. This questionnaire, designed to capture students' perceptions and preferences, included questions about their attitudes towards digital and handwritten L2 writing (McBride & Garcés-Manzanera, 2022). It comprised two sections, each with 23 Likert-scale questions, corresponding to the two writing modalities. This dual approach enabled us to compare

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students' self-reported views on digital versus handwritten L2 writing. Additionally, this approach supported the use of inferential statistics to address our research questions.

As can be seen in Table 2 below, the questionnaire was crafted in Spanish, which was the native language of all the participants. This choice was made to enhance comprehension and avoid any potential confusion due to language barriers. The questions covered a range of topics, including the purpose of writing (whether academic or informal), the participants' confidence in their writing abilities, cognitive factors that might influence the learning effectiveness of writing, and their perceptions regarding the difficulty level of writing in an L2. These diverse aspects were carefully chosen to provide a comprehensive view of how students perceive and interact with different writing formats in a second language setting. The questionnaire for the digital mode was identical except that the references to handwriting (*a mano*, in Spanish) were replaced with digital writing (*por ordenador*, in Spanish).

Table 2

Questionnaire items (McBride & Garcés-Manzanera, 2022)

Pregunta	Descripción
1	Suelo escribir a mano en inglés con la siguiente frecuencia
2	Escribo a mano en inglés en mi trabajo y/o estudios
3	Suelo escribir a mano en inglés cuando he de realizar comunicaciones formales
4	Me siento cómodo escribiendo a mano en inglés
5	Escribo a mano para comunicarme con amigos/familia
6	Me gusta escribir a mano en inglés
7	En el entorno académico suelo escribir a mano en inglés
8	Considero que se me da bien escribir a mano en inglés
9	Escribir a mano en inglés me ayuda a retener conceptos mejor
10	Suelo coger apuntes en inglés a mano
11	Suelo escribir a mano mis redacciones en inglés
12	Suelo apuntar a mano palabras nuevas en inglés
13	Escribo a mano más en inglés que en mi primera lengua cuando estoy estudiando
14	Suelo escribir a mano para resolver problemas cuando aprendo inglés
15	Escribir a mano tareas en inglés me resulta difícil
16	He recibido clases para aprender a escribir a mano en inglés
17	Me distraigo con frecuencia cuando escribo a mano en inglés
18	Planifico mi escritura en inglés con un borrador a mano

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19	Suelo escribir un plan previo en inglés a mano antes de escribir
20	Cuando escribo a mano en inglés, suelo hacer más pausas
21	Soy capaz de organizar mis pensamientos en inglés cuando escribo a mano
22	Suelo hacer esquemas a mano en inglés
23	Considero que puedo estructurar bien un texto en inglés escrito a mano

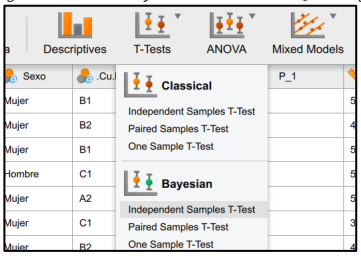
Choosing the right statistical approach: why Bayesian?

Typically, L2 research is conducted within a frequentist statistical framework (as in our first study), utilizing traditional statistical tests, with descriptive statistics, or in other cases different from our own, which may based on values such as *f* and *t* (for instance, in inferential statistics), the *p*-value, and increasingly, effect size. However, as highlighted by Norouzian *et al*. (2019), the prevalent reliance on null hypothesis significance testing has recently come under scrutiny. Criticisms center on the potential for misleading extrapolations of observed effects to larger populations. Consequently, Bayesian hypothesis testing is being increasingly considered as a viable alternative in L2 research contexts. The Bayesian statistical approach allows for a more nuanced understanding of the variability in student perceptions as it incorporates both existing evidence and new data. In essence, Bayesian hypothesis testing differs from frequentists methods in that it includes prior beliefs and updates the probability of a hypothesis in light of the new evidence (that is, the data gathered), making it particularly suitable for exploratory studies in educational contexts (see Shikano, 2019 or Andraszwicz *et al.*, 2015).

Building on the previous information, we opted for using JASP as a software for the analysis for a number of reasons: (1) JASP offers Bayesian analysis for basic statistical tests, featuring parameter estimation and the Bayes factor hypothesis testing based on the default *Cauchy* value, which is a weighting scheme (Jeffreys, 1961; Love *et al.*, 2019); (2) the fact that classical counterparts to frequentist methods are present in Bayesian analyses in JASP makes it a more inclusive option. Figure 4 below displays how well incorporated Bayesian analyses are, facilitating the user's and researcher's tasks by incorporating the frequentist (or classical) method with the Bayesian one.

Figure 4

Layout of classical and Bayesian test results in JASP software



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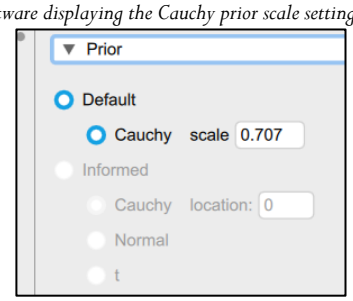
In line with the above information, Figure 5 displays the *Cauchy* value which, in accordance with JASP standards, is set at 0.707. This value is chosen based on the premise that effect sizes are likely to be small in many research scenarios, including SLA and L2 research, where large effect sizes are less common. Such a setting facilitates a non-directional approach in hypothesis testing and offers a versatile alternative (Berkhout *et al.*, 2023).

Figure 5

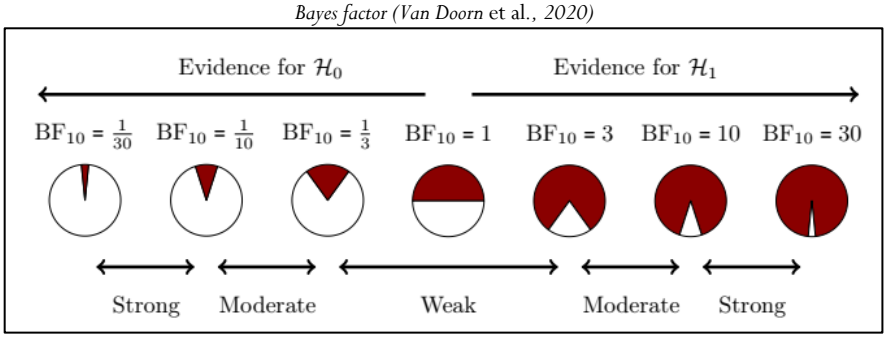
Interface of JASP software displaying the Cauchy prior scale setting for Bayesian analysis



Along these lines, in our study, *Bayes factor* statistic was used as a substitute to *p*-value. In fact, Bayes factor is a statistic that "expresses the comparative evidence for one hypothesis (e.g., alternative hypothesis) over another hypothesis (e.g., null hypothesis)" (Norouzian *et al.*, 2019, p. 3). Bayes factor replaces a p-value and is based on a classificatory scale, as seen in Figure 6 which allows us to determine the extent to which our hypothesis is supported by the study data.

Figure 6

Bayes factor (Van Doorn et al.*, 2020)*



Analysing the data with JASP

In our study, we adhered to a data processing methodology in JASP that aligns with the approach outlined in section 3.1. The primary aim of our research was to examine the potential variance in students' perceptions across survey items, particularly comparing traditional writing methods with digital writing techniques in first and third-year students, which was the independent variable in our study. To this end, we employed non-parametric Wilcoxon signed-rank tests for within-group comparisons and non-parametric Mann-Whitney U tests for between-group analyses (McBride & Garcés-Manzanera, 2022). Due to the space constraints in this paper, we will concentrate solely on one test to demonstrate the utilization of JASP for conducting our statistical analyses in research.

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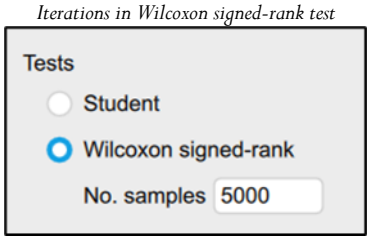
Delving into the specifics of our first analysis, related to the first research question, several key decisions shaped our approach. We retained the default *Cauchy* value as set by JASP. This decision was driven by the limited prior research in the domains of SLA and L2 learning, which presented challenges in gathering pre-existing data. In essence, maintaining the default setting appeared to be the most prudent approach.

Furthermore, we configured the Bayesian variant of the non-parametric Wilcoxon signed-rank test to perform 5000 iterations (see Figure 7 below). This decision was based on the premise that a higher iteration count could more accurately reflect the posterior distribution of the model's parameters, thereby yielding more reliable results. Such an approach is indicative of JASP's capability to integrate traditional frequentist tests (like t-tests or Mann-Whitney tests) into a Bayesian framework, offering a more nuanced view of data analysis.

Figure 7

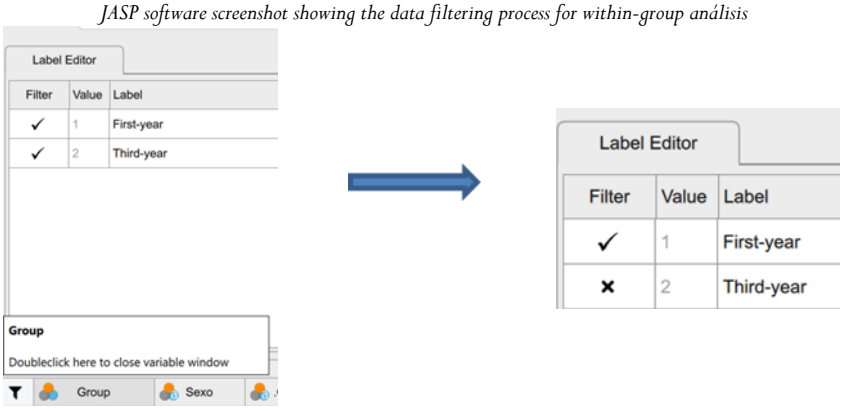
Iterations in Wilcoxon signed-rank test



To address the initial research question, we utilized JASP for segregating the data into distinct groups. This facilitated the execution of within-group analyses. Specifically, we conducted a Wilcoxon signed-rank test separately for first-year and third-year participants. The process of segregation and analysis in JASP is illustrated in Figure 8.

Figure 8

JASP software screenshot showing the data filtering process for within-group análisis



Subsequently, the results from the within-group analysis for first-year participants are presented. This analysis focuses on identifying the variances in their perceptions of traditional versus digital writing. The relevant findings are depicted in Figure 9 (McBride & Garcés-Manzanera, 2022).

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Figure 9

Results of the survey questions by first-year undergraduate students (McBride & Garcés-Manzanera, 2022)

Question	Pen-and-paper writing	Digital writing	BF10	W	Rhat
1	3.16 (0.94)	3.95 (1.15)	42.847	100.000	1.010
2	3.83 (1.04)	4.11 (0.98)	0.353	110.000	1.002
3	2.79 (1.14)	3.60 (1.29)	54.144	73.000	1.005
4	4.02 (1.01)	4.07 (1.10)	0.180	149.000	1.000
5	1.46 (0.90)	3.86 (1.37)	54712.923	3.000	1.051
6	3.62 (1.27)	3.86 (1.03)	0.357	107.500	1.000
7	3.53 (1.27)	4.11 (0.95)	1.824	145.500	1.001
8	3.46 (1.12)	3.81 (1.07)	1.438	68.000	1.000
9	3.76 (1.23)	3.04 (1.17)	13.436	273.500	1.002
10	4.09 (1.08)	2.53 (1.20)	382.288	584.000	1.007
11	3.30 (1.38)	3.97 (1.08)	1.353	161.000	1.002
12	3.81 (1.33)	2.79 (1.48)	32.628	379.500	1.000
13	2.93 (1.33)	3.32 (1.34)	0.866	121.000	1.000
14	3.11 (1.19)	2.55 (1.24)	1.534	441.000	1.001
15	1.74 (1.00)	1.90 (0.94)	0.277	72.500	1.000
16	2.14 (1.33)	1.72 (1.20)	1.028	185.000	1.001
17	2.02 (0.91)	2.76 (1.19)	49.926	63.000	1.001
18	2.62 (1.32)	2.69 (1.37)	0.179	120.000	1.000
19	2.55 (1.41)	2.30 (1.22)	0.245	228.000	1.000
20	3.16 (1.27)	2.95 (1.06)	0.283	245.000	1.000
21	3.72 (1.05)	3.44 (1.14)	0.458	186.000	1.000
22	2.97 (1.12)	2.02 (1.08)	219.247	341.500	1.007
23	3.67 (0.94)	3.76 (1.06)	0.188	73.000	1.000

In the Bayesian Wilcoxon signed-rank test output, several key elements are noteworthy. First, the Bayes Factor, denoted as BF_{10}, reflects the strength of the evidence favoring one hypothesis over another. A higher BF_{10} value suggests more robust support for the alternative hypothesis. Next, the test statistic W, central to the Wilcoxon Signed-Rank Test, evaluates the level of evidence supporting the research hypothesis. This evaluation hinges on whether there is a significant deviation in the data. Particularly in studies with small sample sizes, like ours, a high W statistic typically signals strong evidence in support of the hypothesis.

Finally, Rhat, an essential diagnostic tool in Bayesian statistics, is used to assess the convergence of Markov chain Monte Carlo (MCMC) simulations. This diagnostic, especially relevant in the analysis of iteration chains, becomes

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critical. A Rhat value nearing 1 suggests that the MCMC chains have successfully converged to the target distribution. Such convergence is vital as it bolsters the credibility of the Bayesian estimations produced by the MCMC algorithms.

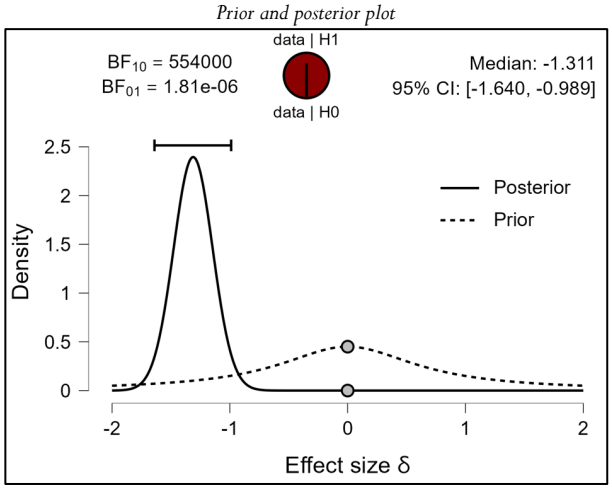
JASP provides all these additional values - besides the key BF_{10} - in an attempt to validate the evidence existing to reject the null hypothesis. From the technical perspective, using JASP for Bayesian statistics is a process made easy given the user-friendly software interface, but equally important, because of the output it produces. Likewise, when the results of this study were presented at a conference, which required a more visual presentation of the data, a series of plots were devised by JASP: Prior and Posterior plot (Figure 10 and Bayes factor robustness check (Figure 11).

The depicted Prior and Posterior plot serves as a visual representation of a Bayesian statistical analysis, contrasting initial assumptions (prior) against updated beliefs after considering new evidence (posterior). The solid line indicating the posterior distribution peaks distinctly to the left of zero, suggesting a negative effect size. This inference is substantiated by the posterior median at -1.311, with a 95% credible interval stretching from -1.640 to -0.989, confidently excluding zero. Such a distribution conveys a statistically significant negative effect, implying that the observed data substantiates a real underlying phenomenon rather than mere chance.

Complementing the density curves, Bayesian Factor values (BF_{10} and BF_{01}) quantify the evidence for the alternative hypothesis over the null hypothesis. A strikingly high BF_{10} value of 554000 robustly favors the alternative hypothesis (H1), while the minuscule BF_{01} value of 1.81e-06 diminishes the likelihood of the null hypothesis (H0), almost to the point of exclusion. This strong statistical support for H1 is visually echoed in the accompanying pie chart, where the shaded area predominates, suggesting a negligible chance for H0. The graph summarizes a rigorous quantitative assessment, indicating a substantial and statistically significant negative effect size that aligns with the research hypothesis.

Figure 10

Prior and posterior plot



Next graph (Figure 11 below) illustrates a Bayesian Factor (BF_{10}) analysis that evaluates the strength of evidence for an alternative hypothesis (H1) against a null hypothesis (H0) across varying widths of a *Cauchy* prior. The

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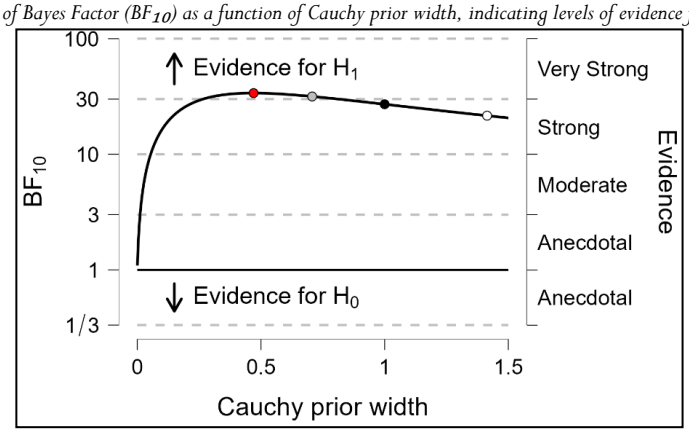
horizontal axis represents the *Cauchy* prior width, a parameter that influences the degree of certainty or uncertainty in the prior distribution. The vertical axis, marked with a logarithmic scale, shows the BF_{10} values, indicating the relative evidence for H1.

The curve on the plot commences with strong support for H1 at a narrow *Cauchy* prior width, reflected in a high BF_{10} value. As the prior width increases, indicating a more uncertain and wider range of prior beliefs, the BF_{10} value decreases, suggesting diminishing evidence for H1. This trend continues until the evidence becomes merely anecdotal at larger prior widths. However, the BF_{10} value never drops below 1, which would indicate evidence for H0; hence, across all prior widths, the data tends to support H1 more than H0.

A red dot on the curve indicates a specific prior width where the evidence for H1 is particularly strong. This point falls within the 'Strong' category on the evidence scale, which ranges from 'Anecdotal' at the lowest end to 'Very Strong' at the highest. The evidence levels are delineated on the right side of the graph, providing a quick reference to interpret the BF_{10} values. Overall, the graph communicates that while the strength of the evidence for H1 varies with the choice of prior, it consistently favors H1 over H0 within the observed range.

Figure 11

Graphical representation of Bayes Factor (BF_{10}) as a function of Cauchy prior width, indicating levels of evidence for hypotheses H1 and H0



Reflections on using JASP for frequentist methods

To conclude this section on the use of Bayesian statistics in L2 research and in particular, on L2 writing, it is essential to consider several crucial aspects: Firstly, despite the widespread reliance on *p*-values, Bayes factors (BF_{10}) provide a more nuanced perspective on the strength of the alternative hypothesis. Unlike the dichotomous nature of significance in frequentist statistics, Bayes factors offer a continuum for evidence assessment, akin to effect sizes, facilitating a more comprehensive understanding of research findings (Norouzian *et al.*, 2018). Secondly, the frequent occurrence of small sample sizes in L2 research underscores the significance of Bayesian statistics. This methodology is particularly effective

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in addressing the limitations of frequentist approaches, such as susceptibility to Type I and II errors, thereby ensuring more robust and reliable statistical conclusions.

Conclusions

This paper has aimed at demonstrating the capabilities of JASP as a data analysis tool within second language research, more specifically, within studies on L2 writing. As described, JASP is able to provide frequentist analysis for studies which include simple experimental designs, or small sample sizes, by carrying out T-tests, providing descriptive data and effect sizes, for example. That being said, it is common knowledge that many statistical packages are geared toward frequentist analyses, particularly SPSS, which has been widely used in the field of SLA and is well-known for its extensive set of procedures for data analysis.

However, one of the main benefits of JASP is the fact that it is an open-source software, meaning it is freely available for anyone to download, whereas more traditionally used data analysis software tools are commercial products and require a license to be able to access them. Additionally, JASP is equally friendly in terms of user interface, making it more accessible to early career researchers. In terms of Bayesian statistics, JASP stands out for its emphasis on Bayesian methods, which can certainly be advantageous for specific data sets, particularly when dealing with smaller sample sizes or when incorporating prior knowledge. As demonstrated in this paper, JASP was able to provide detailed statistical analyses on the L2 data under study. However, it is important to note that, given the novelty of using JASP in SLA research, and when compared to other tools which have a longer history, JASP does not have a wealth of online and offline resources thus far. That is, despite other tools having a large quantity of tutorials, books, and even online resources for their use, JASP is still an emerging analysis tool for many research fields and although the tool itself provides a range of educational resources, tutorials and explicative documents, there is still a general lack of specific tutorials within the SLA field.

Ultimately the choice between using JASP in favor of any other available data analysis tool will highly depend on the specific requirements of the research in question as well as the researcher's familiarity with statistical methods. Notwithstanding, with this paper, we want to highlight the versatility of JASP in implementing both frequentist and Bayesian approaches and call for more research to be explicit, not only in the data analysis procedure, but also in the data analysis tools implemented. By doing so, researchers within the field of second language acquisition can gain more insights into the ways in which we, as a field, are carrying out data analysis, and which tools we are able to implement for the specific data in question.

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