Transitivity Patterns in Results Section of Aerospace Research Articles: A Comparison of Experimental and Simulation–Based Studies

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***Abstract*—Scientific discourse practices vary across disciplines and research designs. As a frontier field where experimental and simulation–based approaches are routinely combined, aerospace engineering provides a productive venue for examining how different research paradigms are linguistically realized. In this situation, this study compares transitivity patterning in experimental and simulation–based results within a Systemic Functional Linguistics framework. Two corpora were compiled from the AIAA Journal, including Results sections from ten experimental articles and ten simulation-based articles, totaling 27,701 and 24,485 tokens respectively. Using UAM CorpusTool 6.2.0, clauses were coded for process types, participant roles, and circumstance types. Distributional differences were tested in SPSS 26.0, and recurrent process-participant-circumstance configurations were qualitatively interpreted. The analysis shows broad convergence in circumstance profiles, indicating shared condition anchoring across research types. In contrast, systematic variation concentrates in the process-participant core: simulation results favor relational processes and carrier-centered realizations, whereas experimental results display a complementary prominence of material processes and more outcome–oriented role profiling. These findings suggest method–sensitive grammatical defaults shaped by model-based versus measurement-based evidential orientations and offer practical implications for concise, condition-explicit Results writing.**

***Keywords*—systemic functional linguistics, transitivity, Results section, aerospace research articles**

I. Introduction

In aerospace engineering, empirical research is conducted primarily through two approaches: controlled experiments and simulation-based modeling. These two research types dominate the evidence base of the field. It is meaningful to figure out how language realize experiential meaning. Regardless of research design, the Results part is the primary section where findings are reported, evidenced, and stabilized as disciplinary knowledge. Genre-based studies have shown that research article sections are associated with recurrent communicative purposes, and that Results is central to outcome presentation and evidence organization [1]. Understanding how Results sections present findings is, therefore, crucial for both discourse analysis and the teaching of academic writing.

Systemic Functional Linguistics (SFL) provides an explicit account of experiential meaning through the ideational metafunction. Within SFL, the transitivity system models experience via process types, participant roles, and circumstance types, offering a principled lens for examining how technical phenomena are represented as actions, relations, attributes and conditions [2]. Recent SFL-informed studies on scientific and engineering discourse further suggest that technical writing relies on selective linguistic resources to achieve technicality and impersonality, while resource deployment may vary with research practices [3].

However, studies of Results and adjacent sections have predominantly examined move structures, reporting strategies, or phraseological realizations [4], and transitivity-based comparisons of Results reporting across experimental and simulation-based studies within a single disciplinary venue remain scarce. In addition, documented structural variation in Results organization indicates that research type can shape how findings are packaged and interpreted [5], calling for clause-level evidence that links distributional tendencies to meaning-making patterns.

To address this gap, the present study analyzes Results sections from *AIAA Journal* articles and compares experimental and simulation-based texts in terms of transitivity distributions and recurrent process-participant-circumstance configurations.

II. Literature Review

A. Transitivity Studies in SFL

In Systemic Functional Linguistics, transitivity system is a core resource for construing experiential meaning. It specifies how clauses represent actions, events, states and relations through configurations of process types, participant roles, and circumstantial elements.

A major strand of research aligns transitivity with critical approaches to public discourse, especially news and political texts. Studies typically examine how process choices and participant assignments make some social actors more visible than others. Corpus-assisted work on national image construction, for example, traces process-participant configurations to show how media discourse foregrounds or backgrounds agency when representing countries and groups [6]. Diachronic analyses of news reporting similarly suggest that transitivity patterns may shift over time, reflecting changing discursive demands and reconfiguring who is construed as acting and who is construed as affected [7]. Related international studies support the view that systematic coding of processes and participants can provide a principled basis for interpreting responsibility and agency in reporting practices [8]. More recent work has also explored finer-grained quantification, linking transitivity-based patterns to social meanings such as gendered power relations [9].

Methodologically, current transitivity research commonly combines quantitative distributional profiling with context-sensitive interpretation. Frequencies and proportions of process types, participant roles, and circumstances are often used to establish overall patterns, while close analysis of representative clauses explains how particular configurations realize discourse functions [10].

Therefore, this study adopts clause-level transitivity analysis with systematic annotation and manual validation to examine experiential patterning in a specialized academic genre.

B. Scientific Academic Discourse

Research on scientific academic discourse has long been concerned with how knowledge is discursively stabilized as verifiable and shareable disciplinary facts. Importantly, scientific writing is not a uniform style.

Drawing on research articles in physics and aerospace engineering, Dong *et al.* [11] show that the two domains share a tendency toward grammatical metaphor, yet they diverge in their preferred realizations: physics discourse more often relies on relational resources to construe states, properties, and fact propositions, whereas aerospace engineering writing more strongly foregrounds material processes to represent experimental operations and technical procedures. This contrast suggests that engineering discourse is shaped by a procedural and operation-oriented epistemology, where what is done and how it is done become central to knowledge presentation.

Meanwhile, scientific texts do not simply report facts. They also manage alignment with readers. Corpus-based studies informed by appraisal theory indicate that research writing deploys engagement resources to anticipate alternative views, validate commitment, and negotiate the acceptability of arguments [12].

Another recurring theme in the literature concerns variation within engineering discourse itself. Studies suggest that engineering subfields share recognizable generic frames and recurrent rhetorical routines, yet they also exhibit domain-specific preferences in how information is staged and emphasized [13]. Genre-oriented corpus work on technical abstracts also points to relatively stable reporting conventions and a strong tendency toward impersonal, results-focused presentation in science and engineering publishing [14].

Based on these insights, this study examines transitivity patterns in the Results sections of aerospace research articles, comparing experimental and simulation-based studies.

C. Results in Research Articles

The Results section has long been regarded as the part of a research article that stays closest to empirical evidence. Its communicative purposes typically revolve around introducing findings, reporting results, and offering only limited, immediate commentaries that support readers' comprehension of the reported outcomes [15].

In addition, research on structural variation indicates that when article organization is adjusted, Results may absorb some methodological information, foregrounding analytic procedures and operational chains to sustain the credibility and rigor of the reported outcomes [16].

From this perspective, Results is not simply a location where facts are listed. It is a dense discursive space where research activities and outcome states are coordinated into a traceable technical narrative. Therefore, writers face a dual task: presenting findings with minimal overt subjectivity while specifying procedures and conditions that make those findings testable and reproducible.

This is closely tied to experiential meaning at the clause level. It is typically realized through systematic choices of process types and through process-participant configurations that foreground technical entities, parameters, and system states as actors or carriers, while backgrounding human agency. Circumstantial elements further delimit results by specifying conditions, means, scope, and locations, thereby strengthening the procedural and verifiable character of results reporting. These observations make it methodologically plausible to connect genre-based descriptions of Results with clause-based accounts of experiential meaning, narrowing the gap between what Results is expected to do and how it is linguistically achieved [17].

Therefore, this study focuses on Results sections and applies transitivity analysis to annotate process types and process-participant configurations, so as to characterize typical patterns of experiential meaning in results reporting and support subsequent comparison across research designs.

III. Methodology

A. Research Questions

(1) How do the distributions of process types, participant roles, and circumstance types differ and converge between experimental and simulation-based Results?

(2) How are the differences and shared tendencies realized through the process-participant-circumstance configurations to perform Results reporting functions?

B. Research Procedures

This study employs a mixed methods design that integrates quantitative and qualitative analyses. For the quantitative component, Results sections were collected from research articles published in the AIAA Journal. To control for cross-journal variation while maintaining disciplinary representativeness, ten experimental studies and ten simulation-based studies were selected, totaling 27,701 and 24,485 tokens respectively. Only the Results section of each article was extracted to form two comparable datasets.

Guided by the transitivity system in Systemic Functional Linguistics, transitivity resources were coded through a computer-assisted manual procedure in UAM CorpusTool 6.2.0, following explicitly defined operational criteria. The annotation yielded a structured dataset that supports a systematic description of distributional features, including frequencies, proportions, and domain-specific concentration patterns across process types, participant roles, and circumstance types. To determine whether these patterns are systematic rather than incidental, inferential statistics were conducted in SPSS 26.0, examining within-type distributional concentration as well as contrasts between experimental and simulation-based Results.

For the qualitative analysis, it focuses on recurrent process-participant-circumstance configurations in each research type. Representative clauses were selected to illustrate how salient transitivity patterning aligns with common Results reporting purposes

IV. Results and Discussion

A. Distributions within Each Research Type

At the level of process types, shown in Table 1, both datasets are dominated by material and relational processes, but their relative weighting differs. Experimental Results show a higher proportion of material processes, reaching 605 cases and accounting for 52.9% of all processes, whereas simulation Results display a stronger preference for relational processes, with 538 cases and a proportion of 48.7%. The corresponding material proportion in simulation Results is lower, at 461 cases and 41.8%. Verbal processes occur at a comparable and relatively modest level in both datasets, with 71 instances in experimental Results and 78 in simulation Results, representing 6.2% and 7.1% respectively, while the remaining process categories together account for only 3.5% in experimental Results and 2.4% in simulation Results.

Table 1. Distribution of transitivity resources

Category	Experiment	Simulation
Process types (Exp N = 1144; Sim N = 1104)		
Material	605 (52.9%)	461 (41.8%)
Relational	428 (37.4%)	538 (48.7%)
Verbal	71 (6.2%)	78 (7.1%)
Others	40 (3.5%)	27 (2.4%)
Participant roles (Exp N = 1994; Sim N = 1922)		
Carrier	410 (20.6%)	512 (26.6%)
Goal	496 (24.9%)	372 (19.4%)
Actor	440 (22.1%)	353 (18.4%)
Attribute	335 (16.8%)	407 (21.2%)
Range	105 (5.3%)	74 (3.9%)
Others	208 (10.4%)	204 (10.6%)
Circumstance types (Exp N = 1055; Sim N = 942)		
Location	547 (51.8%)	467 (49.6%)
Extent	222 (21.0%)	200 (21.2%)
Manner	193 (18.3%)	178 (18.9%)
Others	93 (8.8%)	97 (10.3%)

Participant-role distributions reveal a similar mix of convergence and divergence. Across both research types, Carrier, Goal, and Actor constitute the most frequent roles, indicating shared attention to entities, outcomes, and agency-like sources in Results reporting. Experimental Results allocate more weight to Goal and Actor roles. Goal reaches 496 cases and 24.9% in experimental Results but declines to 372 cases and 19.4% in simulation Results, and Actor shows the same direction of contrast, with 440 cases and 22.1% in experimental Results versus 353 cases and 18.4% in simulation Results. Meanwhile, simulation Results place greater emphasis on Carrier roles, with 512 cases corresponding to 26.6%, compared with 410 cases and 20.6% in experimental Results. Attribute roles are also prominent in both datasets, particularly in simulation Results where they account for 21.2% compared with 16.8% in experimental Results, while Range remains relatively infrequent in both.

At the level of circumstances, the two datasets show a highly similar distribution. Location is the most frequent type in both, accounting for 51.8% in experimental Results and 49.6% in simulation Results, followed by Extent and Manner with very close percentages across the two corpora.

Overall, Table 1 suggests that variation between research types is most visible in how processes and participant roles are distributed, while circumstantial specification shows broad convergence in Results reporting.

B. Contrasts and Shared Tendencies between Experimental and Simulation Results

1) Process-type contrasts

As shown in Table 2, process-type distributions differ systematically between experimental and simulation Results. The chi-square test yields a value of 39.47 with 5 degrees of freedom, and the difference is significant at $p < .001$. The contrast is primarily driven by two categories. Relational processes are over-represented in simulation Results, as indicated by a standardized residual of 2.92, while material processes are under-represented in simulation Results, with a standardized residual of 2.73.

Table 2. Contrasts in transitivity resources

	χ^2(df)	*p*	Major contributors (std. residuals)
Process types	39.47 (5)	<.001	relational (Sim↑/ Exp↓, z = 2.92); material (Exp↑ /Sim↓, z = 2.73)
Participant roles	58.78 (11)	<.001	carrier (Sim↑/ Exp↓, z = 2.80); goal (Exp↑ /Sim↓, z = 2.62)
Circumstance types	5.64 (7)	.582	role (Sim↑, z = 1.09); contingency (Sim↑, z = 0.81)

[1] Exp↑/Sim↑ indicates over-representation in that research type

Qualitatively, experimental Results show relatively stronger material construals that trace changes in measured variables and their co-variation with conditions.

Example 1: The negative normal force and nose-down moment increase as the pitching angle decreases, and vice versa.

In Example 1, this material construal encodes systematic co-variation across conditions, presenting effects as observable shifts linked to parameter changes.

By contrast, simulation Results often construe findings through relational mapping and classificatory relations.

Example 2: The main peak corresponds to the main frequency of the shock periodic motion.

This relational construal realizes a relational identification, mapping an observed feature to a diagnostic value and thus supporting value-to-meaning interpretation in simulation reporting.

2) Participant-role contrasts

Table 2 also indicates that participant-role distributions differ significantly across the two research types. The chi-square statistic is 58.78 with 11 degrees of freedom, and the result is significant at $p < .001$. The largest contributors are Carrier and Goal. Carrier is over-represented in simulation Results with a standardized residual of 2.80, whereas Goal is under-represented in simulation Results with a standardized residual of 2.62.

This divergence aligns with how each research type packages experiential meaning. In experimental Results, Goal-oriented construals are comparatively more visible when results are framed as measured outcomes or affected variables.

Example 3: The calculated specimen weight in FEM was 3.31 kg, and the measured weight of 3CHELL was 3.40 kg.

In this example, the reporting focus is directed to the quantified outcome as an object of measurement and comparison.

In simulation Results, entities are frequently positioned as Carriers that are assigned properties or bases, producing dense relational descriptions

Example 4: The DEIM models are based on the URANS data.

This Carrier-Attribute realization foregrounds model grounding and supports model-centered reporting through relational attribution.

3) Circumstance-type contrasts

In contrast, Table 2 shows that circumstance-type distributions do not differ reliably between experimental and simulation Results. The chi-square statistic is 5.64 with 7 degrees of freedom, and the result is not significant with $p = .582$. The residual values are small, with role showing a standardized residual of 1.09 and contingency showing a standardized residual of 0.81, which indicates that any fluctuations are not systematic at the corpus level.

At the discourse level, both research types routinely rely on circumstantial framing to stabilize interpretability by specifying conditions, settings, and parameter regimes.

Example 5: The abrupt change in thrust occurs at Mach 5.96.

Experimental Results, for example, frequently anchor effects to explicit operating conditions, as in example 5. Simulation Results likewise employ circumstantial framing to relate predicted outcomes to contextual constraints and parameter contrasts, even when their dominant process-participant patterning differs.

4) Shared high-frequency tendencies

Overall, Table 2 suggests that method-sensitive variation is concentrated in process selection and participant-role profiling, while circumstance deployment remains comparatively stable across the two corpora. Experimental Results strongly foreground material construals and outcome-oriented reporting, consistent with measurement-driven description and effect tracing. Simulation Results show stronger preferences for relational construals and Carrier-centered role structures, which are well suited to property assignment and variable-to-value mapping.

At the same time, the shared reliance on circumstantial framing indicates a common disciplinary orientation toward condition-controlled reporting, providing a broad stage for presenting results as technical and interpretable regardless of research method.

C. Configurational Realizations and Functional Interpretation

1) Configurations in experimental results

Experimental Results exhibit several recurrent process-participant-circumstance configurations that support outcome reporting while maintaining condition-bound interpretation. A dominant pattern is *Material+Actor-Goal+Location*, which occurs 120 times and typically construes observable actions or changes while anchoring them to a specific experimental region.

Example 6: The phase-averaged flag shapes at the midspan of the flags are also added.

Example 6 is one representative instance. A closely related configuration is *Material+Actor-Goal* without an explicit circumstantial element, which appears 105 times and tends to advance the results narrative by foregrounding event progression and outcome completion.

Example 7: The graph ends where the bubble has reached the bottom.

This tendency is illustrated by example 7.

Alongside action construals, experimental Results also rely heavily on relational process to stabilize findings as descriptive statements. The configuration *Relational+ Carrier-Attribute+Location* occurs 120 times and is frequently used to present an effect as a property that holds under a specified condition.

Example 8: The effect occurs earlier and is more notable at higher AoA.

This relational summary construes the finding as a property bounded by a parameter condition, facilitating cross-condition comparison in experimental reporting.

Another recurrent relational configuration is *Relational+Carrier-Attribute*, occurring 56 times, which often supports cautious explanatory framing by presenting a rational account for an observed pattern.

Example 9: This is likely a result of the wide distribution of bubbles sizes.

This function can be seen in example 9.

Considered together, these four configurations indicate that experimental Results recurrently align material resources for change and effect reporting with relational resources for property-based summarization, while location type anchoring helps keep claims interpretable within controlled experimental conditions.

2) Configurations in simulation results

Simulation Results show a compact set of recurrent process-participant-circumstance configurations that foreground modeling states, mapped relations, and condition-bound descriptions. The most frequent configuration is *Relational+Carrier-Attribute+Location*, which occurs 140 times and typically presents a modeled entity or variable as a Carrier while assigning it an Attribute under a specified spatial. This pattern supports stable description.

Example 10: Later, the fluid is subject to another compression in the near wake of the wing.

A representative example is example 10. A closely related configuration is *Relational+Carrier-Attribute* without an explicit circumstance, which appears 80 times and often functions as a concise statement of a modeled tendency, with the circumstantial framing either recoverable from prior context or treated as non-essential at that point in the reporting sequence.

Example 11: However, no other significant change in the mean flow topology is observed.

This is illustrated by example 11. Material construals remain prominent, but they tend to be organized in ways that keep the focus on system behavior and resulting tendencies. The configuration *Material+Actor-Goal+Location* occurs 80 times and often describes increases, decreases, or redistribution effects while anchoring them to a wake region. One example is “As a consequence, the length of the mean recirculated area in its wake is significantly increased.” Another frequent material configuration is *Material+Actor-Goal* without an explicit circumstance, which appears 91 times and typically packages a trend statement as an eventlike change.

Example 12: Conversely, once the separation distance reaches 2m, the net force experiences a significant decrease.

This can be seen in example 12. This material realization presents threshold-conditioned change, foregrounding parameter sensitivity through explicit conditional framing.

Overall, these configurations indicate that simulation Results recurrently align relational resources for state and property-based description with material resources for trend and change reporting, while location-type anchoring remains a salient means of situating claims in computationally defined regions and conditions.

3) Shared Strategies and method-sensitive variants

Across research types, Results reporting draws on a shared set of configurational strategies to present findings as condition-bound and technically interpretable. One recurrent strategy is location-type anchoring within high-frequency configurations, which delimits where an effect holds and constrains the scope of interpretation. This can be observed in experimental reporting such as example 8 and in simulation reporting such as example 10. A second shared strategy is the systematic alternation between change tracking and property-based summarization. Material construals are used to register shifts and effects, whereas relational construals repackage these tendencies as stable descriptions that can be compared across conditions.

Method-sensitive variants lie in the default alignment of resources. Simulation Results more consistently realize reporting through relational *Carrier-Attribute* patterns, supporting variable-to-value mapping and state description, while experimental Results more often realize reporting through material *Actor-Goal* patterns, foregrounding measurable change and outcome profiling. These convergences and variants provide a functional account of the contrasts reported previously and clarify how comparable reporting goals are realized through different experiential defaults.

V. Conclusion

This study compares transitivity patterning in the Results sections of experimental and simulation-based aerospace articles. Across research types, circumstance choices show broad convergence, suggesting a shared disciplinary reliance on condition anchoring to delimit what a result applies to. The main differences concentrate in the process-participant core. Simulation Results favor relational construals and Carrier-centered realizations, which efficiently present model outputs as stable state or property mappings. Experimental Results show a complementary prominence of material construals and a more outcome-oriented role profiling, supporting change-and-effect reporting tied to measurement. Configurationally, simulation writing recurrently aligns relational Carrier-Attribute patterns, whereas experimental writing more often aligns material Actor-Goal patterns.

It also gives the implications for practical writing. For simulation-based Results, relational Carrier-Attribute clauses work well for reporting mapped states, but they should be paired with explicit scope conditions. Key property statements can be anchored by location or range frames and a limited number of material clauses can be used to highlight directional change. For experimental Results, material Actor-Goal clauses support effect tracking, yet long sequences may weaken comparability. Writers can therefore add brief relational summaries at transition points, keep outcome variables consistently in focus, and standardize circumstance framing when shifting across runs or figures.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Shiyan Luo designed the initial research framework, conducted data collection and analysis, and drafted the first version of the paper; Yi Zhang provided guidance on the research design and theoretical direction, and polished the paper's structure and academic expression; both authors have approved the final version of the paper.

References

[1] B. S. C. Kwan and H. Chan, "An investigation of source use in the Results and the closing sections of empirical articles in Information Systems: In search of a functional–semantic citation typology for pedagogical purposes," *Journal of English for Academic Purposes*, vol. 14, pp. 29–47, 2014.

[2] M. A. K. Halliday and C. M. I. M. Matthiessen, *An Introduction to Functional Grammar*, 4th ed. London: Routledge, 2014.

[3] Y. L. Zou, "Review of the academic discourse of mechanical engineering: A corpus–based study into rhetorical conventions of research articles, by T. N. P. Le, M. M. Pham & M. Barlow," *English for Specific Purposes*, vol. 76, pp. 136–138, 2024.

[4] T. M. Bao, H. A. Yan, and W. J. Gu, "Analysis of phraseology attached to moves in SSCI research articles in applied linguistics: taking the step of comparing results with literature as an example," *Journal of Qiqihar University*, vol. 3, pp. 152–155, 2020.

[5] S. C. Chien and W. Y. Li, "Perceptions of supervisors and their doctoral students regarding the problems in writing the doctoral dissertation results section," *English for Specific Purposes*, vol. 76, pp. 14–27, 2024.

[6] W. L. Ma and Y. J. Cui, "A corpus–based study on China's national image: A transitivity perspective," *Technology Enhanced Foreign Language*, vol. 5, pp. 114–121+17, 2020.

[7] J. J. Wu, J. G. Xiong, L. L. Guo, J. He, and Y. Q. Liang, "A diachronic study on the discursive representation of child trafficking in China Daily: A transitivity analysis based on stance nouns," *Foreign Languages Bimonthly*, vol. 4, pp. 77–85, 2023.

[8] N. Akram, M. Yasmin, and A. Sohail, "Perpetuation of rape myths through news reporting on intimate partner violence: A transitivity analysis of Asma Aziz case," *Women's Studies International Forum*, vol. 109, 2025.

[9] J. E. Aaron, "Quantifying transitivity: Uncovering relations of gender and power," *Language Variation and Change*, vol. 36, pp. 123–147, 2024.

[10] K. Wu and Y. Li, "International eco–discourse analysis on the basis of transitivity system: An exemplary study of joint statement between the People's Republic of China and the Russian Federation," *Foreign Language Research*, vol. 2, pp. 34–42, 2025.

[11] L. Dong, A. C. Fang, and X. Qiu, "Shell nouns as grammatical metaphor in knowledge construal: Variation across science and engineering discourse," *Lingua*, vol. 248, 2020.

[12] Y. C. Xu, R. Su, X. Yan, and Y. Kou, "A corpus–based contrastive study of engagement resources in English and Chinese scientific research articles," *Foreign Language Education*, vol. 41, 2020.

[13] N. B. Tatiana, "Engineering discourse through phrase–frames: Pedagogical recommendations," *Applied Corpus Linguistics*, 2026.

[14] J. Y. Guo, "Writing pattern of English research paper abstract in engineering geology based on corpus analysis," *Acta Editologica*, vol. 30, pp. 34–38, 2018.

[15] J. M. Swales and C. B. Feak, *Academic Writing for Graduate Students: Essential Tasks and Skills*, 3rd ed. MI: University of Michigan Press, 2012

[16] Y. Y. Wang, "When methods and results intertwine: An exploration from congruent and metaphorical construal," *English for Specific Purposes*, vol. 78, pp. 109–124, 2025.

[17] A. I. Moreno and J. M. Swales, "Strengthening move analysis methodology towards bridging the function–form gap," *English for Specific Purposes*, vol. 50, pp. 40–63, 2018.