WHAT DO SECTION HEADINGS AND SUBHEADINGS TELL THE READER? A STUDY OF THE MACROSTRUCTURE OF RESEARCH ARTICLES IN THREE ENGINEERING DISCIPLINES

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ABSTRACT. *In this study we analysed section headings and subheadings of 40 RAs in the fields of computing, robotics and telecommunications to identify their macrostructure. Our findings revealed that the standard IMRD model cannot account for all the specific choices regarding organization and headings of individual RAs. Scientific writers split the information into a variable number of sections and subsections and combined generic headings with unconventional ones. Generic and partially generic section headings and subheadings helped the reader understand the way the writer presented and organized contents. But when the terminology was topic-specific and did not indicate the rhetorical function of the sections, it was necessary to consult the abstract or the introduction and study the overall purpose of the RA to recognize its organizational pattern. However, a certain cyclical or symmetrical structure at the lexical and the syntactic levels was usually kept in different sections.*
KEY WORDS: *genre analysis, macrostructure, research article, section headings*

RESUMEN. *Este trabajo analiza el desarrollo de la macroestructura a partir de los títulos y subtítulos de las secciones de un corpus de 40 artículos de investigación de revistas científicas de informática, robótica y telecomunicaciones. Aunque algunos artículos reproducen el esquema IMRD, destaca el número de artículos que presentan variantes. La información aparece segmentada en secciones y subsecciones combinando títulos genéricos y títulos no-convencionales. Los genéricos (y parcialmente genéricos) orientan al lector sobre la manera en que se presenta el esquema organizativo escogido por el autor. Pero cuando la terminología refleja el contenido específico de la sección o subsección y no su función retórica, resulta necesario recurrir al resumen o a la introducción y buscar el propósito general del artículo para averiguar cómo está estructurada la información. Con todo, se suele mantener una cierta coherencia mediante la simetría o iteración léxica y sintáctica de los títulos y subtítulos de las secciones.*
PALABRAS CLAVE: *análisis del género, macroestructura, artículo de investigación, títulos y subtítulos de las secciones.*

1. INTRODUCTION

Over the last 25 years there has been an increasing interest in the study of genre. The most extensively analysed genre of academic writing has been the research article (RA) and much research has been carried out on its organizational pattern. A number of studies have been devoted to validate and complete the Introduction-Method-Results- Discussion (IMRD) model, either dealing with the overall organization of RAs from different disciplines (Nwogu 1997; Posteguillo 1999; Ruiying & Allison 2004; Swales 2004), or focusing on specific RA sections, such as introductions (Swales 1981; Swales 1990; Samraj 2002), results sections (Thompson 1993; Brett 1994), and discussions (Hopkins & Dudley-Evans 1988; Holmes 1997; Skelton & Edwards 2000; Ruiying & Allison 2003). But there is little research on the connection among the different sections and the importance of the section headings in guiding the reader on the organization of complete RAs.

This paper seeks to describe a set of RAs written in English through the analysis of the terminology employed in the titles of sections and subsections. Our study will show that the standard IMRD model cannot account for all the specific choices regarding organisation and headings of individual RAs. The use of unconventional section headings and subheadings indicates that they convey information both on the rhetorical and conceptual levels.

2. METHODOLOGY

In order to carry out the present study, we created a corpus of 40 RAs selected from leading scientific journals in the fields of computing, robotics and telecommunications. The corpus comprises articles written between 2002 and 2003: 12 articles in the specific discipline of computing, 16 texts from journals in the field of robotics and 12 articles in telecommunications. The main reasons for choosing the journals in our corpus were that they are cited in the Science Citation Index (SCI®), they are read by university lecturers and students, and it is in these journals where lecturers and postgraduate students try to publish their research. In the appendix, a full reference list of the texts analysed is included.

Our first task was to extract the macro-organization of each text. Then we analysed the terminology employed in the section headings and subheadings with reference to the widely accepted IMRD framework. We labelled the different section headings and subheadings as generic, partially generic and topic-specific (following Bunton 2002). Section headings and subheadings were generic when they could be used in an Introduction, Method, Results or Discussion section on any topic and discipline, e.g. *Background* or *Numerical results*. In other cases they were partially generic, e.g. *Definition of X* or *Related X research*, where X is a particular topic of the study. On the other hand, topic-specific section headings and subheadings related to some aspect of the research topic: *Stream-Replication-Based Multicast*.

3. RESULTS AND DISCUSSION

Sections tell us how the writer sees the structure of his/her text. For this reason, the terminology employed in the title of each section should serve as a guide to the reader throughout the text.

The number of sections in the 40 RAs in the corpus range from 4 to 12: 6 RAs presented a 4-section structure; 4 RAs presented a 5-section structure; 13 RAs were organised in 6 sections; 9 RAs had 7 sections; 3 RAs had 8 sections; 2 RAs 9 sections, and 3 other RAs had, respectively, 10, 11 and 12 sections.

The conventional generic section headings in 2 of the 4-section RAs reproduce the IMRD structure. They share the opening section heading *Introduction*, although subsequent sections are called differently: while RAS3 presents the titles *Materials and Methods*, *Results* and *Discussion*, AI3 uses *Model, Results and Discussion* and *Conclusion*. Nevertheless, the organizational structure of 38 RAs in our corpus reveals that it is customary to find some deviation from the standard division represented by the IMRD model, although it is still possible to identify this underlying structure.

3.1. *Headings for introductory sections*

The 40 RAs in the corpus present 1, 2 and even 3 introductory sections. The most usual first section heading is the generic term *Introduction*, although 2 RAs use the heading *Motivation* and 1 RA uses *Background*. Only RCIM1 has a topic-specific heading: *Concurrent engineering*; and we can also mention that the 3 RAs from IEEEN present several introductory paragraphs with no section heading.

Besides the first introductory section, 21 RAs include independent sections focusing mainly on either the background or the literature review, maybe because of the relevance of the information they convey (Bhatia 1993). The function of these sections coincides with steps 2 and 3 in Move 1 of Swales's Create a Research Space (CARS) model[1] and they

appear under generic headings (10 RAs), partially generic headings (4 RAs), and topic-specific headings (7 RAs).

3.2. *Headings for method sections*

The 40 RAs in the corpus devote one or more sections to the description of the materials and procedures followed in the study, i.e. the Method section of the IMRD model. 14 RAs dedicate only 1 section to these aspects, 10 RAs have 2 sections, 8 RAs present 3 sections, 3 RAs have 4 sections, 2 RAs consist of 5 sections and 1 has even 7 sections. A high number of sections is devoted to describe the design of a model or an algorithm and to specify their validity in terms of performance and evaluation. This reflects the importance of showing that the study has been conducted under an adequate methodology, allowing the results to be accepted by the scientific community.

14 RAs entitle the first section using the two generic words *method/s and model/s* or else partially generic headings in combination with them. These words are usual in RAs belonging to the fields of computing and robotics, while in telecommunications, the word typically employed is *architecture* (4 RAs). 10 RAs employ other partially generic headings (like *X scheme*, *X approach*) and 9 RAs use topic-specific headings. As for the headings used in subsequent method sections, they are mainly partially generic and topic-specific.

3.3. *Headings for results sections*

In our corpus, results tend to appear in only one independent section (28 RAs). However, in 3 RAs (WN2, IEEEN1 and IEEEN2) there is no specific section at all dealing with results and in 2 RAs (IEETRA2 and ACMTCS3[2]) experimental results appear as a subsection of the method section. It is also noteworthy that the order of the sections presenting results is in some cases cyclical. This happens when the researcher's work involves several proposals or shows results under different conditions. In these cases, the section exposing the results follows the description of a particular model or protocol. The same pattern is repeated when another experiment with a modified model or different elements is presented (IEEEJSAC3)[3].

The function of the first results section is transparent in our corpus because of generic or partially generic headings containing the words *results* and *experiments*. But, when more than one section is devoted to the exposition of results, authors prefer topic-specific headings.

3.4. *Headings for discussion sections*

The main functions of the final sections of RAs are either to comment on the major findings, to come to more general conclusions, or to suggest areas of further research. The 40 RAs include 1 final section generally entitled *Discussion/s* (13 RAs) or *Conclusion/s* (12 RAs). Moreover, 11 out of 40 RAs in our corpus have 2 sections with a closing role and 1 RA has 3 sections, which indicates that the writer considers them important. Their generic headings make reference to the moves and steps that were identified in the Discussion section by Swales (1990) and Ruiying and Allison (2003), indicating a specific-to-general movement. They focus on the importance of the study in the field, and suggest future investigation (*Conclusion*, *Future work, Concluding remarks).*

Most of the RAs in our corpus have separate sections devoted to the presentation and the discussion of results. Only 4 RAs include the discussion in a subsection of the section where findings are presented. However, 7 RAs (IJRR3, AI3, IEEETRA1, IEEEJSAC1, IEEEJSAC2, IEEETB1 and IEEEN3) combine both results and discussion in the same

section using the following generic titles: *Discussion of results, Results and discussion* (2), *Experimental results and discussion/s* (2), *Numerical results and discussion* and *Simulation results and discussion*. In all these cases, a closing section is usually entitled *Conclusion*.

3.5. *Subheadings*

Another relevant characteristic present in 36 out of the 40 RAs in the corpus is that they incorporate subsections and sub-subsections. Although we found subsections in the introductory (10 RAs) and in the concluding sections (8 RAs), the subsections and even the sub-subsections appear mainly in the method and results sections. In contrast with the section headings, the majority of the titles used for the subsections and sub-subsections are partially generic or topic-specific, pointing to some particular aspect of the research. This reflects explicitly not only the rhetoric typical of the genre but also specific contents related to the research.

Partially generic headings make the reader aware of the current move or step and, at the same time, guide him/her through the research carried out and the concepts and issues dealt with. Headings including words like *background, overview, review, previous knowledge, hypothesis, problems, vulnerabilities* or *need* help us to identify a move in the introduction. Words or expressions like *system, participants, device, model, apparatus and materials, description of models, architecture, protocol, algorithm* indicate we are dealing with materials. Others, such as *application, design*, *procedure, strategy, analysis, evaluation criteria, search, practice, variables, constraints, assumptions, data collection* make reference to the method. *Performance, analysis, effect, behaviour, experiments* are related to results. *Comparison, guidelines, perspective, extensions* correspond to the moves for the Discussion section. These nouns are premodified (*The linear arrangement problem* in WN2) or postmodified by clauses referring to a particular topic of study (*Results for the visual search task* in JHCS1; *General problems of modelling visual attention* in AI3;).

Topic-specific headings make it more difficult to identify the IMRD standard pattern. Nevertheless, the cyclical, repetitive or symmetrical pattern of the syntactic structure and the terminology of subheadings in a number of RAs is useful for understanding the rhetorical and conceptual organization of some sections. Careful reading of abstracts and introductions may also help to clarify the purpose of the sections.

A way of maintaining coherence is by repeating the same grammatical structures (*4.1 Building an anomaly detection model / 4.2 Detecting abnormal updates to routing tables / 4.3 Detecting abnormal activities in other layers*, in WN3; *A. Network architecture / B. Node architecture / C. MAC protocol* in IEEEJSAC3). In IJHCS3[4] a MRD pattern is systematically repeated inside 3 sections providing a detailed account of the procedure, results and comments on 3 different experiments. Here, the coherence is kept by repeating the same generic section headings and subheadings. In ACMTCS3[5] it is the repetition of the same subheadings in two different sections presenting results that contributes to coherence. In other cases subheadings share one or more words. In AI1 subheadings sharing the terms *approximation* and *linear response* contribute to guiding the reader in the presentation of three different approximations dealt with in different sections (*3.1 The mean field approximation—linear response / 5.1 The Onsager approximation—linear response / 6.3 The Bethe approximation—linear response*); while in IEEETRA3 the section on experimental results contains subheadings where lexical opposition points to the design of the experiments carried out (*In vitro experiments of drilling / In vivo experiment*).

But inner coherence in the subheadings within a section is frequently manifested in the form of lexical variations in postmodifiers of the same noun, as in *Minkowski sum based on CH / Minkowski sum based on slope diagram* (CAD1) and *Hierarchical selectivity /*

Hierarchical selectivity from coarse to fine / Hierarchical selectivity from far to near (AI3). The variations can also appear in the premodifiers of the same noun, like in WN3 (*3.2 Local detection / 3.3 Cooperative detection*). Another procedure that clarifies the development of the subject is to combine within a particular subheading the words appearing in preceding subheadings (*3.2 Local detection / 3.3 Cooperative detection / 3.4 Intrusion response / 3.5 Multi-layer integrated intrusion detection and response* in WN3).

4. FINAL REMARKS

Our analysis has shown that the IMRD framework is a rhetorical model typically followed by RA writers in computing, robotics and telecommunications at the macrostructure and section heading levels. But this does not mean that all the RAs have the same organizational characteristics and unified section headings. Authors combine generic and partially generic titles with topic-specific headings, particularly in the sections and subsections devoted to describing methods and presenting results or proposing models. Their purpose when organizing information in their RAs seems to be to indicate not only communicative functions but also explicit elements involved in their research. One explanation to this may be that the reader does not usually read the text thoroughly unless he/she is especially interested in it. A way of helping him/her decide whether the contents of the RA will be of any use to him/her is to indicate clearly what every section is about, not only what its role is. However, due to the increasing complexity, diversity and specificity of the methods and fields open to scientific research, any morphosyntactic and semantic resources contributing to the maintenance of coherence are valuable means of guiding the reader throughout the text.

NOTES

1.
Move 1. Establishing a Territory
    Step 1: Claiming centrality, and/or
    Step 2: Making topic generalisation(s), and/or
    Step 3: Reviewing items of previous research
Move 2: Establishing a Niche
    Step 1A: Counter-claiming, or
    Step 1B: Indicating a gap, or
    Step 1C: Question-raising, or
    Step 1D: Continuing a tradition
Move 3: Occupying the Niche
    Step 1A: Outlining purposes, or
    Step 1B: Announcing present research
    Step 2: Announcing principal findings
    Step 3: Indicating RA structure
(Swales 1990: 141)

2.
I. INTRODUCTION
II.QUANTIFICATION OF INSTRUMENT MOTION
    A. Laboratory instrumentation
    B. Intraoperative instrumentation
III. FILTERING ALGORITHMS
    A. Tremor

B. Nontremulous error
IV. SYSTEMS FOR ACTIVE COMPENSATION
A. Design
B. Experimental methods
C. Experimental results
V. DISCUSSION
VI. CONCLUSION
(IEETRA2)
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…
6. AGE-BASED MESSAGE PURGING
6.1 The principle
6.2 Optimized Ipbcast
6.3 Evaluation Criteria
6.4 Results
7. FREQUENCY BASED MEMBERSHIP PURGING
7.1 The principle
7.2 Optimized Ipbcast
7.3 Evaluation Criteria
7.4 Results
(ACMTCS3)

3.
…
III. NETWORK ARCHITECTURE AND PROTOCOL
IV. THEORETICAL PREDICTIONS
V. SIMULATIONS RESULTS
VI. FT-TR NODE ARCHITECTURE
VII. EFFECT OF UNBALANCED TRAFFIC
VIII. DISCUSSION AND CONCLUSIONS

4.
…
4. Experiment I
4.1 Data sets
4.2 Questions
4.3 Visualizations and instructions
4.4 Participants
4.5 Procedure
4.6 Results
4.7 Conclusion
5. Experiment II
5.1 Data sets
5.2 Questions
5.3 Visualizations and instructions
5.4 Participants
5.5 Procedure
5.6 Results
5.7 Conclusion
6. Experiment III
6.1 Participants
6.2 Procedure
6.3 Results
6.4 Conclusion

5.
Same pattern as in note 2 (ACMTCS3).

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APPENDIX

Journals and RAs in computing

ACMTransactions on Computer Systems (ACMTCS)
ACMTCS1 "Design and Evaluation of a Conit-Based Continuous Consistency Model for Replicated Services". Vol.20 No3 August (2002) 239-282.
ACMTCS2 "Run-Time Support for Distributed Sharing in Safe Languages". Vol.21 No1 February (2003) 1-35.
ACMTCS3 "Lightweight Probabilistic Broadcast". Vol.21 No4 November (2003) 341-374.

Computer-Aided Design (CAD)
CAD1 "Improvements to algorithms for computing the Minkowski sum of 3-polytopes". Vol.35 (2003) 1181-1193.

CAD2 “A parametric interpolator with confined chord errors, acceleration and deceleration for NC machining”. Vol.35 (2003) 1249-1259.
CAD3 “Mechanistic modelling of the milling process using an adaptive depth buffer”. Vol.35 (2003) 1287-1303.

Computer Vision and Image Understanding (CVIU)
CVIU1 “Robust parameterized component analysis: theory and applications to 2D facial appearance models”. Vol.91 (2003) 53-71.
CVIU2 “Facial asymmetry quantification for expression invariant human identification”. Vol.91 (2003) 138-159.
CVIU3 “Locating human faces within images”. Vol.91 (2003) 247-279.

International Journal of Human-Computer Studies (IJHCS)
IJHCS1 “The effect of spatial layout of and link colour in web pages on performance in a visual search task and an interactive search task”. Vol.59 (2003) 327-353.
IJHCS2 “Internet attitudes and Internet use: some surprising findings from the HomeNetToo project”. Vol.59 (2003) 355-382.
IJHCS3 “Visualizations of binary data: A comparative evaluation”. Vol.59 (2003) 569-602.

Journals and RAs in Robotics

Artificial Intelligence (AI)
AI1 “Approximate inference in Boltzmann machines”. Vol.143 (2003) 19-50.
AI2 “Towards an analytic framework for analysing the computation time of evolutionary algorithms”. Vol.145 (2003) 59-97.
AI3 “Object-based visual attention for computer vision”. Vol.146 (2003) 77-123.
AI4 “Dynamic belief revision operators”. Vol.146 (2003) 193-228.

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IEEETRA1 “Visually Guided Landing of an Unmanned Aerial Vehicle”. Vol.19 No3 June (2003). 371-380.
IEEETRA2 “Toward Active Tremor Canceling in Handheld Microsurgical Instruments”. Vol.19 No5 October (2003). 793-800.
IEEETRA3 “Stem Cell Harvesting Device With Passive Flexible Drilling Unit for Bone Marrow Transplantation”. Vol.19 No5 October (2003). 810-817.

International Journal of Robotics Research (IJRR)
IJRR1 “Artificial Muscles: Actuators for Biorobotic Systems”. Vol.21 No4 April (2002). 295-309.
IJRR2 “Persistent Passive Hopping and Juggling is Possible Even With Plastic Collisions”. Vol.21 No7 July (2002). 621-634.
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Robotics and Autonomous Systems (RAS)
RAS1 “Real time gait generation for autonomous humanoid robots: A case study for walking”. Vol.42 (2003) 107-116.
RAS2 “A multisine approach for trajectory optimization based on information gain”. Vol.43 (2003) 231-243.

RAS3 “Developing a robot visual system using a biologically inspired model of neuronal development”. Vol.45 (2003) 111-130.

Robotics and Computer Integrated Manufacturing (RCIM)
RCIM1 “Implementation of concurrent engineering: A survey in Italy and Belgium”. Vol.19 (2003) 225-238.
RCIM2 “Modeling, scheduling and simulation of product development process by extended stochastic high-level evaluation Petri nets”. Vol.19 (2003) 329-342.
RCIM3 “Algorithmic selection of a disassembly sequence of a component by a wave propagation method”. Vol.19 (2003) 439-448.

Journals and RAs in Telecommunications

IEEE Journal on Selected Areas in Communications (IEEEJSAC)
IEEEJSAC1 “A Study of waveband switching with multilayer multigranular optical cross-connects”. Vol. 21 No 7 September (2003) 1081-1095.
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WN2 “Pushing dependent data in clients-providers-servers systems”. Vol. 9 (2003) 421-430.
WN3 “Intrusion detection techniques for mobile wireless networks”. Vol. 9 (2003) 545-556.

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IEEEN2 “An agile optical layer restoration method for router failures”. March/April (2003). 38-42.
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IEEE Transactions on Broadcasting (IEEETB)
IEEETB1 “A Hybrid CATV/256-QAM/OC-48 DWDM System Over an 80-km LEAF Transport”. Vol. 49, No1, March (2003). 97-102
IEEETB2 “Temporal Compensated Motion Estimation With Simple Block-Based Prediction”. Vol. 49, No 3, September (2003). 241-248
IEEETB3 “Fast Simulation of Diversity Nakagami Fading Channels Using Finite-State Markov Models”. Vol. 49, No 3, September (2003). 269-277.