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Visuals and text in scientific articles

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An analysis was conducted on the differential use of visuals in articles published in the 2005 issues of ergonomics periodicals. Review papers present the smallest number of visuals, mostly organigrams and qualitative tables. Methodological papers follow, with a below average use of all visuals. Modelling/theoretical papers use the largest number of visuals, particularly sketches, curvigrams, organigrams, and equations. Experimental papers follow, with the highest use of histograms, dot curvigrams, and photographs. Finally Enquiries/observations use mostly quantitative tables. Such results point to the relative specificity of visuals and should be helpful in training future scientists and improving guidelines in periodicals.

All scientists preparing a paper either for a periodical or a congress presentation face the task of integrating messages between two media: text, either printed or spoken, and visuals for printing or projection. Printed text receives considerable attention from editors as well as professional associations, and is subject to precise instructions to authors, publicised in most periodicals. But visuals are, in general, subject to much less restricting directions: Puhan, ter Riet, Eichler, Steurer, and Bachmann (2006) showed that, out of 120 "core medical journals", only 7 provided instructions for graph construction. In the field of ergonomics, the guidelines published by Gillan, Wickens, Hollands, and Carswell (1998) are an exception.

Little attention has been paid to the use of visuals in communications by scientists over the years. Yet the use of visuals has been increasing over the last century, as shown by Bazerman (1988) for physics, and in a more general survey by Gross, Harmon, and Reidy (2002). In a limited sample of 100 papers from most frequently cited periodicals, these authors showed that while 33% of papers had numbered figures with a title in the first quarter of the 20th century, this rose to 54 % in the second, 86% in the third and 100% in the last quarter.

The reference study on the use of visuals in scientific papers is probably that of Cleveland (1984), who studied the use of the 377 graphs in the 249 articles of volume 207 (1980) of "Science". A graph was defined as a figure that "had scales and conveyed quantitative information", including statistical maps. The author classified graphs according to the number of variables presented in each figure. Two-variable graphs accounted for 83% of the total, one-variable figures (including "bar charts, histograms, point graphs [points plotted along a line], and miscellaneous") made up approximately 12%, and three-variable figures ("statistical maps and miscellaneous")

close to 5%. Bar charts alone accounted for about 5% of the total, histograms 3%, and point graphs and miscellaneous each 2%.

Cleveland also computed the "fractional graph area" (the fraction of space covered by graphs) of unspecified graphs used in 2,850 papers published in 57 different journals. The median fraction was .066, with values ranging from 0 to 0.310. The author grouped the journals into three categories, and showed that the space allocated to graphs (and the number of graphs per paper) decreased from the natural sciences to mathematics and social sciences.

Even though Cleveland considered it unwise to compare individual disciplines, due to what he described as too small a sample, Arsenault, Smith and Beauchamp (2006) chose to reconsider some of his data in order to explore the use of visuals amongst disciplines of different "hardness" (as rated through "impressions" collected from respondents). They computed the occurrence of visuals in 180 articles randomly chosen from 50 of the periodicals surveyed by Cleveland. They counted 2,629 "inscriptions" of all kinds, which gave an average of 14.6 inscriptions per article. Out of these, 17% were defined as "graphs", and 10% as "Non Graphic Illustrations" (NGI: "diagrams, pictures and maps"); "Non Visual Illustrations" (NVI) were made up of tables (15%), and "equations blocks" (58%). The total number of inscriptions per paper varied only slightly between "soft" and "hard" disciplines. It was shown that the use of graphs and NGI was strongly correlated to perceived "hardness", while that of NVI was not. For graphs, "soft" disciplines used almost exclusively curves (87%), while "hard" disciplines used fewer (65%) and turned to scatterplots (30%). For NGI, "soft" disciplines turned to line art in 98% of cases, while "hard" disciplines did so in 72% of cases, and used photographs in 28%. The authors concluded that these differences could be caused by editorial practices, but also by the difference in the nature of data.

Most studies conducted on the use of graphs, like Cleveland's paper, are primarily concerned with the quality and efficiency of graphical material, referring primarily to statistics and methodology, and at times to principles of graphic design. A few of these studies present data on the differential use of types of graphs and graphic material that we will briefly consider.

Busch-Lauer (1998) presented data on 126 "non verbal elements" (NVE) collected in 30 "quality medical papers" from unspecified sources. In this sample, tables accounted for 57.2% of the total, bar charts 3.9%, line charts 13.4%, schemata 6.4%, and real images 19.1%.

Cooper, Schreiger, and Tashman (2001) and Cooper, Schreiger and Close (2002) conducted an analysis of "graphs" (excluding tables and flowcharts as well as descriptive illustrations) in research papers (excluding case reports, reviews and methodology papers) from two medical journals. Their data show a total of 0.87 graphs per paper in the Annals of Emergency Medicine (AEM) – 35% bar charts, 33 % point graphs, 6% scatter plots, and 20% survival curves. But in the Journal of the American Medical Association (JAMA), 1.14 graphs per paper were used, with a different distribution – 31% bar figures, 27% point graphs, but 23% scatter plots and only 6% survival curves.

Bowen and Roth (2002) conducted a comparative study of visuals in textbooks and ecology journals. Their data, only presented in a histogram, show that periodicals rely massively on plots (approximately 0.36 per page), tables (~0.21 per page), and equations (0.21 per page), and up to 10 times more rarely on photographs and drawings, diagrams and maps.

This rapid survey allows us to identify three problems. The first deals with the nature of the graphic material covered. Different authors include different visuals in their corpus, including or not tables, photographs or specific types of graphs. Moreover, the names used to designate the visuals are at variance. Denominations like

"diagrams", "charts", "plots", "graphs", and even "histograms" have a different coverage or are defined differently by different authors (Desnoyers, 2011). The resulting level of inaccuracy makes it difficult to compare results from different authors, and is a major impediment in any attempt at analyzing or comparing visuals at a finer level than that allowed by broad categories. The second problem is that the study of visuals is frequently made in relation to disciplinary fields, under the implicit premise that disciplines would be homogeneous in their use of graphical material. One would, of course, expect that disciplines concerned with morphology would use different sets of visuals than, for example, mathematics. But within a single discipline, even within a single disciplinary periodical, articles differ in their scope and intent, from theory to practice, from fact finding to methodology and so on, which could have an impact on visuals used. The third problem is that of the units used for computation: it is difficult to relate fractional graph areas to visuals per page or per paper or percentage of different visuals.

Faced with these questions, one can try and develop an ergonomic perspective, linking work activities and tools. As communicators, scientists perform various activities; they review literature, report on results from observations as well as experimentations, and present techniques and methods, or theories and models. These activities yield different types of papers in periodicals, which have much in common with different literary genres. The concept of genre is not frequently used in the study of science communication, except to distinguish between categories like reports, theses, oral communications, posters, papers in periodicals, etc. However Swales (2004), in his major work on research genres, proposes a distinction between three genres of articles: experimental, theoretical and review. The often-referred to Publication Manual of the American Psychological Association (2010) recognizes the existence of five major types of articles: empirical studies, literature reviews, theoretical articles, methodological articles and case studies. Gross et al. (2002) propose a more detailed classification of papers published in periodicals into eight categories: experimental, theoretical, methodological, observational, observational/theoretical, experimental/theoretical, mathematical, and review. Such a classification gives a better representation of the diversity of communication activities in periodicals.

Visuals are one of the most important tools of science communication. There is considerable diversity in these tools but also a definite specificity: a curve in a Cartesian graph serves a different purpose than a statistical map or an organizational chart. From an ergonomic perspective, it might be expected that different communicational activities require different tools, and there could be a correspondence between types of visuals used and specific communicational genres. Pursuing such a relationship means relying on an unambiguous classification of visuals, avoiding polysemic terms and overlapping categories that plague studies of the use of graphic material in science communication. Desnoyers (2011) has developed such a taxonomy and nomenclature, based on Linnaean principles which require hierarchical, collectively exhaustive, and mutually exclusive categories. In this taxonomy, three global classes are distinguished, based on the information contents and predominant type of signs in the visuals. A first class comprises visuals made of alphanumeric signs: they are called "typograms" since, in essence, they use typographical symbols. A second class is called "analograms" since all are based on an analogue scale, an analogy between a numerical value and a dimension of a calibrated (usually Cartesian) space; here visuals use graphic signs (dots, curves, areas, figures) to transcribe data. A third class is called "cosmograms" and consists of iconic signs, and representations of objects and places. Each class is then subdivided according to a specific criterion: type of content and layout in the case of typograms,

type of graphical sign in the case of analograms, and production technique in the case of cosmograms. Such a taxonomy and nomenclature offer the possibility of finely tuned analyses and comparisons.

It appeared to us that such an ergonomic perspective, linking specific communicational tools to specific communicational activities, could be the basis for an in-depth analysis of visuals-to-text relations in scientific articles. It is this correspondence between types of visuals and genres of papers in scientific periodicals that we investigated and report on in this paper.

Methods

We chose to investigate the visuals-to-genre correspondence within a single discipline, in order to better bring out the effect of genre and avoid inter-disciplinary biases. Ergonomics offers a wide span of contributions from theoretical to applied perspectives, and from field studies to laboratory experimentations. Four printed periodicals, amongst the most influential in ergonomics, were chosen to represent this diversity, as described in Table 1.

All the papers published in 2005 in these four journals were analyzed (with the exception of editorials), which gave a corpus of 295 papers with a total of 3,814 pages and 2,192 visuals of different types. The papers were classified in five different genres, in a simplified version of the classification by Gross et al. (2002), as presented and defined in Table 2.

"Visuals" were defined as all printed material outside the main body of text, usually numbered and designated under the terms figure, table, equation or quotation. This material was classified according to the taxonomy presented in Table 3, adapted from Desnoyers (2011).

The number, specific type and surface area of all types of visuals were computed for each paper. An attempt to relate these data to number of pages or words per paper was unsuccessful, probably due to differences in format, layout, and font size between periodicals; it was therefore decided to express results in terms of visuals per paper, which, as shown by Cleveland (1984), is highly correlated to fractional page area used by the visuals.

Table 1. Characterization of the four journals studied. Content description is based on the information published by the journals on their websites

Periodical	Editor	Content
TIES: Theoretical Issues in Ergonomics Science	Independent, USA	Theory, methodology, history, epistemology
ERGO: Ergonomics	The Ergonomics Society, GB	Theoretical and applied contributions, ergonomics and related fields
HF: Human Factors	Human Factors and Ergonomics Society, USA	Theoretical and applied contributions, human-machine environments
AE: Applied Ergonomics	The Ergonomics Society, GB	Practical applications of design and ergonomic research

Table 2. Description and statistics of paper genres as applied to the ergonomics journals considered.

Paper genre	Description	Number in corpus	Proportions
REV: review	Summary and assessment of published material	16	5 %
ENQ: enquiry	Results from studies using questionnaires, interviews, observation or accident data analysis	66	22 %
EXP: experimentation	Results obtained by subjects performing a task in a controlled environment	138	47 %
MOD: modelling	Presentation of a physical or mathematical model, theorization	35	12 %
MET: methodology	Description of study approaches	32	11%
OTH: others	Hybrid or unclassifiable paper	8	3%

Results

Global distribution of visuals

Table 4 presents the data on the distribution of all types of visuals. The column at the right shows the distribution of all classes and orders of visuals, all papers combined. Of the 2,192 visuals, 375 are cosmograms, which makes them the least used of visuals, at 17% of the total. Within these, photograms are the more numerous (63% of cosmograms), followed by pictograms (33%), with a very small number of hybrid compositions.

Globally, the second class in rank is that of analograms, their number of 696 accounting for 32% of all visuals. Amongst analograms, histograms are the most frequent order (41%), closely followed by puncti-curvigrams (31%), then curvigrams (21%), and finally punctigrams (4%). Not a single morphogram was observed and circular histograms were very rare. A small percentage of analograms (17/2192, 0.08%) could not be classified, as they were montages combining at least two different orders of analograms.

The total number of typograms is 1,121 which makes them the most abundant class with 51% of all visuals. Within typograms, cellulograms are by far the most frequently used order, making up 69% of types, followed in order by equations (16%), organigrams (9%), and scripts (6%). Cellulograms are the most widely used single group of all visual orders, their number (774) representing 35% of all visuals. They are mostly used to present quantitative data: the results presented in Table 5 show that this is the case for 69% of cellulograms (536 out of 774).

Table 3. Taxonomy of the main groups of visuals in journal papers. Following Linnaean nomenclature, the larger groups are classes, subdivided into orders, which are eventually divided into families.

Class	Order	Examples
Typograms (linguistic statements using the signs of typography)	Scriptograms (textual or alphanumeric material)	Numerical: equations Alphabetical: phrases, bullet lists
	Organigrams (relations between graphically separated nominal entities)	Flow charts, networks, Venn diagrams
	Cellulograms (matrices with quantitative, nominal or mixed data)	All sorts and shapes of tabular presentations
Analograms (based on graphic signs representing quantitative data, using an analogy between a numerical value and a dimension of a calibrated space)	Punctigrams (dots) descriptions, comparisons of sets of (individual data)	Scatterplots, linear "dot graphs"
	Curvigrams (curves) (tracing of computed or approximated relations between bivariate data)	Straight, segmented, curved or stepped line tracings in cartesian space
	Puncti-curvigram (hybrid visual combining curves and dots)	Curve traced superimposed on dots
	Histograms (areas) (description, comparison of data grouped by categories)	Pies, bars and columns
	Morphograms (figures) (multivariate data in different populations)	Polygons, Chernoff faces
Cosmograms (iconic signs representing material entities)	Photographic	Photographs of places, subjects, equipment, etc.
	Pictographic	Drawings representing places, objects, etc.

Table 4. Distribution of visuals by paper genre. Under the name of each genre is the number of corresponding papers. In each cell the first number reports the total amount of visuals, and the second is the number per paper. Underlined italics indicate the minimal value per type, while bold characters indicate a maximum value.

	REV n= 16	ENQ 66	EXP 138	MOD 35	MET 32	OTH 8	TOTAL 295
ALL COSMOS	5 *0.31*	80 1.21	198 **1.43**	50 **1.43**	39 1.22	3	375 1.27
PICTOS	3 *0.19*	20 0.30	66 0.48	23 **0.66**	11 0.34	0	123 0.42
PHOTOS	1 *0.06*	55 0.83	128 **0.93**	23 0.66	26 0.81	3	236 0.80
HYBRIDS	1 0.06	5 0.08	4 .03	4 0.11	2 0.06	0	16 0.05
ALL ANALOS	11 *0.69*	91 1.38	480 **3.48**	69 1.97	35 1.09	10	696 2.36
CURVIS	6 0.40	23 *0.35*	74 0.54	29 **0.83**	12 0.38	5	149 0.51
PUNCTIS	1 0.07	7 0.11	9 0.07	11 **0.31**	0 *0.00*	0	28 0.10
P C	2 *0.13*	24 0.36	158 **1.14**	21 0.60	12 0.38	0	217 0.74
HISTOS	2 *0.13*	36 0.55	226 **1.64**	5 *0.14*	11 0.34	5	285 0.97
OTHERS	0	1	13 0.09	3	0	0	17 0.58
ALL TYPOS	40 *2,50*	314 4,76	465 3,37	191 **5.46**	90 2,81	21	1121 3.80
CELL	21 *1.31*	251 **3.80**	366 2.65	62 1.77	65 2.03	9	774 2.62
EQUAT	4 0.25	3 *0.05*	87 0.63	79 **2.26**	3 0.09	6	182 0.62
SCRIPTS	0 *0.00*	38 **0.58**	7 *0.05*	8 0.23	9 0.28	1	63 0.21
ORGANI	15 0.94	22 0.33	5 *0.04*	42 **1.20**	13 0.41	5	102 0.35
TOTAL	56 *3.5*	485 7.35	1143 8.28	310 **8.86**	164 5.13	34 4.25	2192 7.43

Table 5. Distribution of the different families of cellulograms amongst paper genres.
Q = Quantitative, N = nominal, MIX = mixed cellulograms.

	REV	ENQ	EXP	MOD	MET	OTH	TOTAL
CELL Q	6	172	290	31	29	8	536
	0.38	**2.61**	2.10	0.89	0.91		1.82
CELL N	8	50	30	25	25	1	139
	0.50	**0.76**	*0.22*	0.71	**0.78**		0.47
CELL MIX	7	29	46	6	11	0	99
	0.44	**0.44**	0.33	*0.17*	0.34		0.34
TOTAL	21	251	366	62	65	9	774
CELL	1.31	**3.80**	2.65	1.77	2.03		2.62

Visuals and genres of papers

Comparisons between genres are made easier by referring to the number of visuals per paper. The 2,192 visuals yield 7.43 visuals per paper globally. Modelling papers contain the most (8.86 visuals per paper), closely followed by Experimentations, while Review papers have the lowest score (3.50 visuals per paper).

The relative distribution of the different classes amongst genres can be read from Table 4 and is visualized in Figure 1.

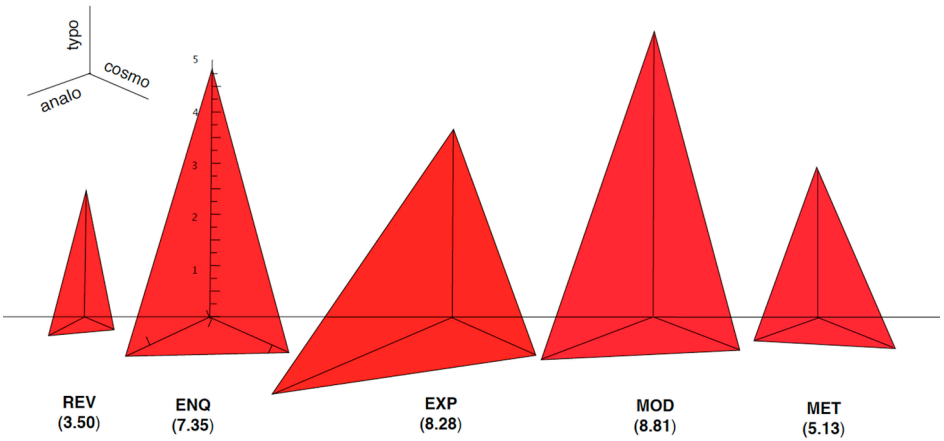

Figure 1. Polygons showing the distribution of classes of visuals amongst genres of papers. Numbers in parenthesis refer to the total of visuals per paper in this genre.

The most striking finding in this figure is that the shapes of four of the polygons, with the exception of Experimentations, are rather similar, revealing that the four genres differ more by their total number of visuals than by the proportions of each class. Experimentations stand out due to their maximal use of analograms; at 3.48 per paper, this is 47% above the global average for analograms. Modelling papers are the largest users of visuals, mostly due to their maximal use of typograms; the figure of 5.46 per paper is 44% higher than the average. They also share a maximum use of cosmograms (1.43 per paper) with Experimentations, but this is only 13% above the average. Enquiries show an important although sub-maximal use of typograms. Methodological papers do not stand out in their use of any classes of visuals; their use of cosmograms is equal to the average, and they are below average for both analograms and typograms. Finally, Reviews owe their rank as minimal user of visuals to a combined minimum in all three classes.

These global views, however, conceal the finer differences that show up from an analysis of the distribution of the different orders within each class of visuals.

Cosmograms

In the case of cosmograms, it can be seen in Table 4 that globally, hybrid visuals (combining photographic and pictographic material) only make up a negligible part of the total and that photograms are used almost two times more frequently than pictograms.

Across paper genres, Experimentations and Modelling are the largest users of cosmograms, at 1.43 per paper, but only 13% above the average of 1.27. As can be seen from Figure 2, the ratios of photograms to pictograms are similar in Enquiries, Experimentations and Methodologies. There are two outstanding genres. Modelling papers show a maximum use of pictograms at 0.66 per paper, some 57% above the average. Reviews papers only make a small use of cosmograms, but this is due primarily to the lack of photograms: at .06 per paper, their use represents about 8% of the average.

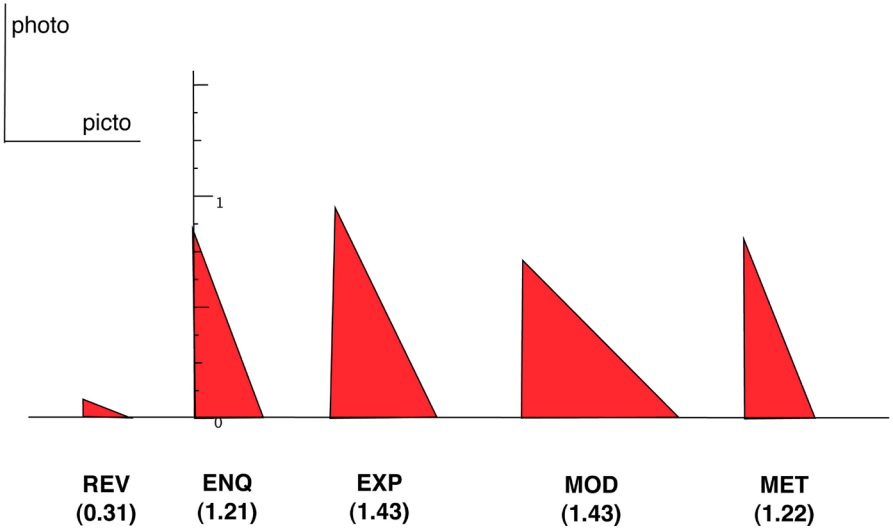

Figure 2. Polygons showing the distribution of cosmograms amongst genres of papers. Numbers in parenthesis refer to the total of visuals per paper in this genre.

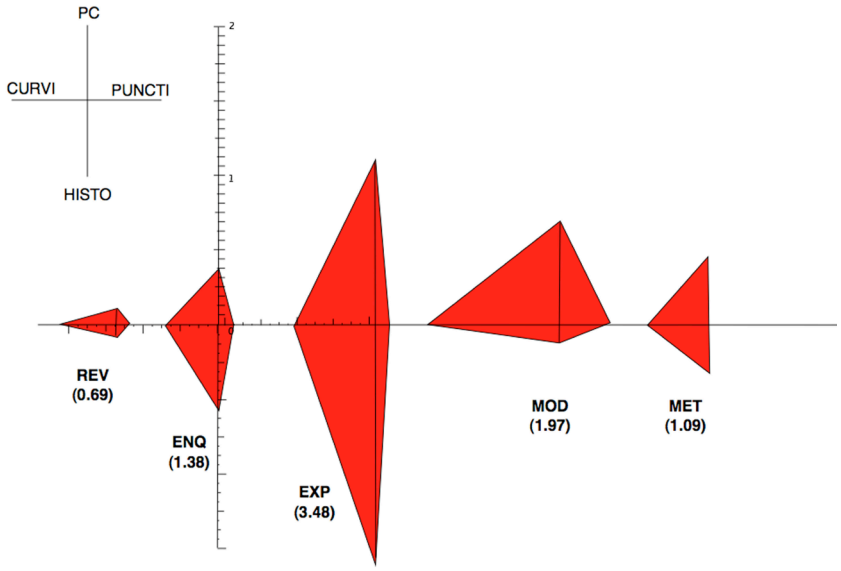

Figure 3. Polygons showing the distribution of orders of analograms amongst genres of papers. Numbers in parenthesis refer to the total of analograms per paper in this genre.

Analograms

Figure 3 illustrates the distribution of the orders of analograms amongst paper genres. The shapes of the polygons demonstrate important disparities between genres. Experimentations, which show by far the largest number of analograms globally, have the highest number of histograms at 1.64 per paper, 69% above the average; they also have the highest number of puncticurvigrams, at 1.14 per paper, 54% above the average. Modelling studies are the second largest user of analograms. They show the largest share of curvigrams at 0.83 per paper, 63% above average; they also have the largest number of punctigrams (0.31 per paper, 68% above average) and the second smallest proportion of histograms. Enquiries follow; at 1.38 analograms per paper, their notable features are a minimal use of curvigrams and a second rank using histograms. Methodologies, at 1.09 analograms per paper, never use punctigrams, and show below average values for all the others. Finally, Reviews, at 0.69 analograms per paper, have minimal scores for both PC and histograms and close to average values for curvigrams and punctigrams. There is therefore a large disparity in the use of the different orders of analograms throughout paper genres. Genres differ less in their use of curvigrams.

Typograms

Table 4 and Figure 4 show that typograms are the most widely used class of visuals, but again the different orders are used quite differently amongst genres. Modelling papers make the highest use of typograms (5.46, 44% above the average); this is mostly due to the highest prevalence of equations (at 2.26 per paper, 2.6 times the average) and of organigrams (at 1.2 per paper, 2.4 times the average), while cellulograms are below average. Enquiries papers also rely sizably on typograms (at 4.76 per paper). Here, as shown in Table 5, it is the maximal use of cellulograms of all types that makes the difference, at 3.8 per paper; the use of scripts is also a distinct feature

at 0.58 per paper, 1.76 times the average. Experimentations papers rely mostly on cellulograms; here quantitative cellulograms are ten times more frequent than nominal. Methodologies papers use few typograms, and mostly cellulograms; they share first position in the use of nominal cellulograms with Enquiries papers. Finally, Review papers have the lowest prevalence of typograms, and within these no scripts, the lowest prevalence of cellulograms but the second largest use of organigrams.

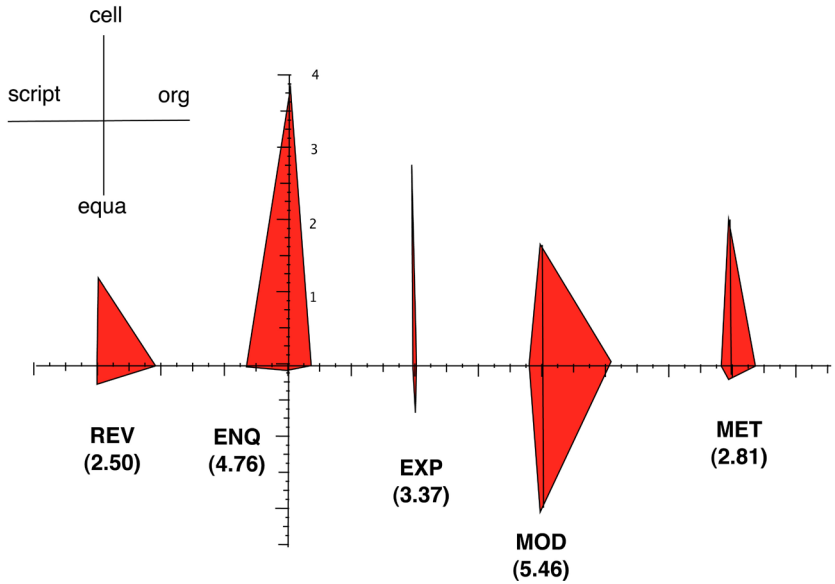

Figure 4. Polygons showing the distribution of orders of typograms amongst genres of papers. Numbers in parenthesis refer to the total of analograms per paper in this genre.

Table 5. Distribution of the different families of cellulograms amongst paper genres. Q for Quantitative, N for nominal, MIX for mixed cellulograms.

	REV	ENQ	EXP	MOD	MET	OTH	TOTAL
CELL Q	6	172	290	31	29	8	536
	0.38	**2.61**	2.10	0.89	0.91		1.82
CELL N	8	50	30	25	25	1	139
	0.50	**0.76**	*0.22*	0.71	**0.78**		0.47
CELL MIX	7	29	46	6	11	0	99
	0.44	**0.44**	0.33	*0.17*	0.34		0.34
TOTAL CELL	21	251	366	62	65	9	774
	1.31	**3.80**	2.65	1.77	2.03		2.62

Discussion

Genres, classes, and units

Only 8 of the 295 papers could not be classified in the five categories used to distinguish genres of papers in ergonomics. If this supports the view that these categories are satisfactory for this particular discipline, we have to consider that, in other fields, other categories would have to be considered, for example case studies in the health sciences. Likewise, the taxonomy of visuals, as we have used it here, allows the classification of all but 17 analograms (0.08% of visuals) that were all montages of two or more different analograms. This would indicate that such a taxonomy is complete enough at least for ergonomics, the field we investigated. However, it would have to be tested in other fields to verify its adequacy or completeness.

We have used the number of visuals per paper as a convenient unit for comparison, supported by the finding by Cleveland (1984) that fractional graph area was "due more to variation in the number of graphs than to variation in average size"(p 265). One of the inconveniences of such a measure is that length of papers could have an impact on the data. This does not seem to be the case in our study: for example, Reviews published in TIES, with the lowest use of visuals, were actually slightly longer than Modelling papers (20.9 pages vs. 18.2) which contained the most. In a study comprising a more diversified source of articles, paper length should, however, be taken into account, and other units (perhaps visuals per page or per word) should be considered.

Global proportions of visuals

Assuming a reasonable correspondence between categories of visuals used by different authors, simple calculations can be made on some of their results in order to generate comparable data. The outcome of such calculations is summarized in Table 6.

Regarding the total number of visuals per paper, our only possible comparison is with data by Arsenault et al. (2006) who obtained a figure almost twice our count of 7.43 per paper. This could be related to the very high diversity of disciplines represented in their sample. The frequency of photograms and pictograms use in our data can only be compared with results by Busch-Lauer (1998) for similar categories, and for both, the data are similar.

As for analograms, the data by different authors vary from 0.87 to 2.51 per paper, compared to our figure of 2.36; considering the differences in disciplinary coverage and the various definitions of this class of visuals, these differences would seem to be minor. The data by Cooper et al. (2001, 2002) show five times more punctigrams in JAMA than in AEM, which the authors do not explain; our data offer a value comparable to the average of both these medical journals. Puncti-curvigrams seem to be used 1.3 to 2.5 times more frequently in ergonomics periodicals than in the medical journals. Histograms seem to be used three to eight times more in ergonomics journals.

Typograms are, by far, the most frequently used type of visuals, which was an unexpected finding. We have few comparisons possible for typograms, since these are not frequently studied. Our results for cellulograms are quite similar to those of Arsenault and Busch-Lauer. The most striking difference would be for the use of equations, where Arsenault reports a very high score of 8.46 per paper compared to our 0.62. This might be due to disciplinary influences, Arsenault having included ten periodicals from the fields of economics and physics, where one would expect a more frequent use of these.

These similarities and differences are to be interpreted with caution. The disciplinary fields covered by the studies are at times quite different; but even within the medical papers, the results recorded by the two

Table 6. Distribution of visuals per paper in different studies.

	Cleveland	Arsenault	Busch-Lauer	Cooper** AEM	Cooper** JAMA	This paper
All Visuals		14.26				7.43
Cosmos						1.27
-photo			0.8			0.80
-picto			0.27			0.42
Analos	1.51*	2.51		0.87	1.14	2.36
-curvi	1.26					0.51
-puncti				0.05	0.27	0.10
-PC			0.57	0.29	0.31	0.74
-histo	0.12		0.17	0.30	0.35	0.97
Typos						3.80
-cell		2.17	2.4			2.62
-equa		8.46				0.62
-scriptos						0.21
-organi						0.35

"Graphs" of different authors were assimilated to analograms. Cooper's "point graphs" were considered as PCs here, while Busch-Lauer's "bar charts" and Coopers "bar figures" were included in histograms. Busch-Lauer's "schemata" were assimilated to pictograms and "original images" to photograms.

* Cleveland counted 377 "graphs", and volume 207 of Science included 249 " research reports". Contrary to others, his "graphs" included statistical maps. The number of curvigrams was estimated from his data on the percentage of graphs consisting of "two variable graphs", while the number of histograms combines data for his two categories "bar charts" and "histograms."

** Calculations using the number of "graphs" per paper reported by authors and percentages reported for each sub group relative to the total.

Cooper studies and in Busch-Lauer are at times remarkably different. We have no information on the genres of papers included in the different studies, except that Cooper et al. (2001, 2002) excluded case reports, reviews and methodological papers from their sample. No information is available on paper length or on subject matter. In Cleveland's (1964) study, interpretation is also difficult since the largest array of disciplines is covered, and the relatively low score of 1.51 "graphs" per paper could be influenced by the fact that papers in the periodical "Science" are usually shorter than in many periodicals, and seem to concentrate mostly on enquiries and experimentations.

It might be pointless to try and link the frequency or distribution of visuals in ergonomics papers to the disciplines characterised as a "hard" or a "soft" science, as was done in the study by Arsenault et al. (2006). While Experimental work makes up 47% of the papers in our

corpus, Enquiries papers yield 22%, and this distribution might illustrate the heterogeneous nature of the discipline. Modelling, Methodological and Review papers, which are produced in both "hard" and "soft" disciplines, globally make up 28% of papers here. Comparisons between disciplines might be less instructive than further studies taking genres of papers into account.

Visuals and genres of articles in periodicals

The distribution of classes of visuals through paper genres does show noticeable disparities, which are probably best explained by referring to the properties of article genres and affordances of the different visuals.

Review papers are an effort at assessment and synthesis, and therefore probably rely more on verbal comment than on visuals: this should explain their low global use of almost all forms of visuals. Reviews use the smallest proportion of cosmograms, which could be due to their rare references to specific environments or material entities. These papers usually do not report on much specific or new quantitative data, which would explain the lowest frequency of analograms, useful in presenting such data. They contain mostly curvigrams, and again, this would seem logical since these are useful to show the most abstract, mathematical or quasi-mathematical form of relations between variables. In the case of typograms, Reviews are distinct from other genres in two ways. Their lowest frequency of quantitative cellulograms would be expected since they rarely present raw quantitative data. Their frequent use of organigrams (second only to Modelling papers) would also be expected, since these visuals are adept at showing the global organisation of systems or procedures.

Enquiries papers make use of visuals at a level comparable to the global average. Here, cosmograms are used at a level almost identical to the average. Enquiries papers frequently produce large sets of multivariate data that are difficult to render in a visual form, which would explain their low use of analograms. These data are more frequently reported in cellulograms, and not surprisingly, Enquiries papers are the largest users of these visuals. In typograms, they also show the largest use of script, which are in most instances quotations from interview answers, typical of this genre.

At a global level, Experimentations papers are characterised by a high prevalence of cosmograms, particularly photograms, which in our corpus seems to be related to the frequent use of photography to describe experimental set-ups. Experimentations papers lead in the global use of analograms, due to a widespread use of histograms and curvi-punctigrams presenting univariate or bivariate experimental results. Punctigrams, which would present bivariate data without reference to a mathematical model, and pure curvigrams, that would only present an abstract derivation of data, are only rarely used in this context. Typogram use in general is average: not surprisingly, the use of scripts and organigrams is lowest, and equations close to the general average. Cellulogram use is high (second only to Enquiries papers), due to quantitative cellulograms presenting experimental data, as would be expected.

Modelling studies are a genre devoted to generalization and abstraction. They make use of the largest number of all visuals combined. They share the highest prevalence of cosmograms with Experimentations papers, but here this is due to pictograms depicting models of physical entities. Modelling articles are second to Experimentations in their global use of analograms, but here this score is largely due to the use of curvigrams and PC, the most abstract analograms. They globally show a massive use of typograms, and amongst these, the largest number of organigrams and equations; this feature would be expected considering the abstract level of equations and the efficiency of organigrams at describing structure as well as functional properties of systems.

Methodological papers, finally, are the most difficult to characterise in their use of visuals. Their use of cosmograms is close to average for both pictograms and photograms. Their use of analograms is rare, nearly below the averages for all four orders. This would be expected, since this genre rarely offers experimental data. Typograms are again below average, close to the minimum score of Review papers. Like Reviews, Methodological papers are therefore not genres that are conducive to the use of visuals.

Choosing visuals

As we have indicated before, none of the articles we analyzed contained morphograms; likewise, none are reported in the other studies we mentioned. These figures, and particularly polygons such as those we used in Figures 1 through 4, are an excellent tool to show distributions of a certain number of variables in a given number of populations. Many of the papers we analyzed contained such data, but these were only presented in cellulograms which were, at times, quite large. It is surprising that polygons, which are frequently used, for example, in consumer information, would be overlooked by the scientific community.

We also noted an almost total absence of circular histograms or pie charts in our data. Much attention has been paid to these visuals by analysts, for example by Tufte (1983), who considers this type of visual to be one of the least efficient. Bertin (1977) is of the same opinion. Cleveland and McGill's (1985) findings of the relative inefficiency of angular representations in the evaluation of graphic values reinforce this view. Circular histograms are used frequently in popular science and in the press, and their absence in our corpus probably conveys a certain distrust of their efficiency.

Conclusion

An ergonomic perspective leads us to consider the communication work of scientists as made up of different types of activities, which translate into different genres of articles published in periodicals. Likewise, since different activities are usually performed using different tools, we need to try to discover which tools correspond to each type of activity and genre of papers. Such an investigation requires a sound classification of both articles and visuals, which we tried to achieve by working out a set of genres and developing a Linnaean taxonomy and nomenclature for visuals. Both of these will have to be submitted to more trials to assess their relevance and efficiency.

Nevertheless, we have been able to demonstrate strong links between article genres and specific visuals. Some of these associations are particularly strong: between Modelling papers and the use of equations and organigrams as well as pictograms; between Experimental papers and photograms, and more specifically analograms, particularly histograms and puncti-curvigrams; and between Enquiries papers and cellulograms and scripts. Reviews require few visuals, except for organigrams, and papers dealing with methodology show little specificity. As revealed by the polygons in our Figures, it is patterns of multiple associations that emerge, rather than links between a genre and a specific visual.

The taxonomy we have used, and the type of data we have obtained, could be useful in at least two domains. The first is the training of young scientists in the use of relevant and efficient visuals, which frequently receives little attention in educational programs, as noted amongst others by Trumbo (1999). Pauwels (2006) goes further and insists on the necessity of developing a true visual literacy amongst scientists, a domain that receives little attention, as Bertin (1977) had already underlined. Although there could be a number of local initiatives in

this area, there seems to be no information available on these; studies and training in science communication are much more centred on the media and popularization, rarely on communication between scientists.

The second domain could be that of guidelines development. Many periodicals have no detailed directions for visuals, while others simply refer authors to one of the professional associations who have produced such guidelines, like the American Psychological Association or the American Medical Association. As we have mentioned, denominations of visuals as well as design considerations are at variance amongst these, and some recommendations seem erroneous. Authors waste time and effort in analysing and adapting to the specific, and at times unpredictable requirements of every other periodical. One wishes that there could be a joint endeavour by editors, publishers, and professional associations to develop common guidelines for all types of visuals.

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