A Comprehensive Overview of Visual Design of Process Model Element Labels

Agnes Koschmider[1(✉)], Kathrin Figl[2], and Andreas Schoknecht[1]

[1] Institute of Applied Informatics and Formal Description Methods, Karlsruhe Institute of Technology, Karlsruhe, Germany
{agnes.koschmider,andreas.schoknecht}@kit.edu
[2] Institute for Information Systems and New Media, Vienna University of Economics and Business, Vienna, Austria
kathrin.figl@wu.ac.at

Abstract. Process model element labels are critical for an appropriate association between a symbol instance in a model and the corresponding real world meaning. Disciplines, in which an efficient presentation of text labels is crucial (e.g., cartography) have continuously improved their visualization design techniques for labels since they serve as effective cognitive aids in problem solving. Despite the relevance of labels for information exploration, surprisingly little research has been undertaken on the visual design of element labels of business process models. This paper fills this gap and provides a comprehensive overview of visual design options for process model element labels. First, we summarize the findings existing in the diverse areas of literature relevant to visual display of process model element labels. Second, we analyze the status quo of visual design of element labels in common business process modeling tools indicating only little layouting support. Third, we give recommendations regarding the visual design of element labels. To our knowledge, this is the first comprehensive analysis of visual design of process model element labels.

Keywords: Information visualization · Layout · Process model · Text labeling

1 Introduction

"Labels play a critical role at the sentence (diagram) level, in distinguishing between symbol instances (tokens) and defining their correspondence to the real world domain" [1, p. 764]. Thus, if users do not (fully) understand the tokens (text labels of process model elements), an improper notion of the real process might arise. In the same vein, [2, p. 203] denote that the "Tagging [of] graphical objects with text labels is a fundamental task in the design of many types of informational graphics." Research in the field of informational graphics has made a high effort to identify the best strategies to label areas (such as oceans in cartography), lines and points (e.g., in graphs) and to find efficient algorithms to solve these tasks (e.g., to find the maximum possible number of labels and the maximum size for labels while avoiding label-label overlaps [2, 3]).

Against this background, surprisingly little articles address the visual design of labels of process model elements, while semantic issues of labeling process model

M. Reichert and H.A. Reijers (Eds.): BPM Workshops 2015, LNBIP 256, pp. 571–582, 2016.
DOI: 10.1007/978-3-319-42887-1_46

elements have received higher attention. Semantic issues tackled in these articles [4–7] are either related to recommendations on labeling styles or to the revision of the vocabulary of process model element labels. Although process modelers follow these modeling guidelines recommended for labeling process elements[1], the reader can still be handicapped in his/her task execution due to an improper recognition of the label (as a result of an improper visual design). In order to support appropriate task execution of model readers, both issues (semantics and visual design of labels) must be addressed. This paper is dedicated to the investigation of visual design of process model element labels since no modeling guidelines exist for this issue so far.

To identify relevant influence factors for an efficient visual design, first, a solid analysis of related disciplines emphasizing text labels is required. Process model element labels are a concatenation of words with its own style conventions and they can be considered as a specific form of natural language text. There is a long tradition of research on word recognition in natural language text. However, it is open which findings from reading research can be transferred to visualization criteria of modeling labels. Experimental research in the area of source code comprehension has for instance shown that there are fundamental differences between reading source code and reading natural language prose [8]. Similarly, the generalizability of reading research to process model element labels might be limited; there could for instance be interaction effects between the underlying graphical modeling language and the use of natural language in the labels.

To study the status quo of practical implementations of visual design we firstly describe visual variables to define the frame of our study. Afterwards, we analyze the layouting support for labels offered by common business process modeling tools, in Sect. 3. Section 4 describes which recommendations from related disciplines can be applied to the visual design of process model element labels. Based on this discussion we identified several open issues on visual variables of element labels, which need to be addressed by research. The open issues are discussed in Sect. 5. Section 6 highlights how our contribution complements related work. Finally, the paper ends with a summary and outlook in Sect. 7.

2 Visual Design of Process Model Element Labels

The business process task represented by a process element in a visual model is described through a label typically using natural language. The label can be expressed with different linguistic styles. Current modeling guidelines advocate using a verb-object style [4], in which the object is described by a noun (or noun compound) and the action is described by a verb in infinitive. Further common labeling styles for process model elements are a deverbalized-noun + "of" + noun (e.g., evaluation of

[1] In the context of this paper, we subsume active (activities) and passive (events) elements of the modeling language under the term 'process model elements', but disregard labels of gateways.

flights), a noun + deverbalized-noun (e.g., flight evaluation) or a gerund + noun (e.g., evaluating flights).[2]

The natural language used to label the process model element can be designed in different visual ways. The visual design options are best discussed by the "graphic design space" [1], which bases on the visual variables of Bertin. There are 8 visual variables: horizontal and vertical position, shape/form, size, brightness (originally termed "value"), direction/orientation, texture (hue) and color. These variables can be applied to any form of graphic object, and also to textual objects like labels [9]. Most of Bertin's variables (shape/form, size, direction/orientation and color) are applicable for process model element labels.[3] Beside these visual variables, depending on the process modeling notation the label placement (e.g., within, above, below) might vary. We characterize this specificity of process model element labels by adding the new variable "position". The perception of the label might also be influenced by the space specified to enter letters. We consider this issue in our context by adding a further new visual variable termed "segmentation". Table 1 displays related visual variables for process model element labels, which are discussed in detail in Sect. 4.

Table 1. Visual variables (visual encoding) on process model element labels

Visual Variable	Example		
Shape/Form	evaluate flight	Evaluate Flight	EVALUATE FLIGHT
Size	evaluate flight	evaluate flight	evaluate flight
Direction/ Orientation	evaluate flight	evaluate flight	evaluate flight
Color	evaluate flight (red)	evaluate flight (blue)	evaluate flight (green)
Position	evaluate flight	evaluate flight	evaluate flight
Segmentation	evaluate flight immediately	evaluate flight immediately	evaluate flight immediately

To study the implementation of visual design of process model element labels in practice, seven common process modeling tools were investigated. The results are summarized in the next section.

[2] The role who executes the task might also be attached to the label (e.g., check flight by clerk).

[3] Texture and brightness are not elaborated separately in our context. Brightness and texture (hue) are considered as components of color aesthetic (color is scaled down to hue and brightness). Consequently, identical assumptions are applied for hue and texture as for color.

3 Visual Design Support in Business Process Modeling Tools

In this section, the support for visual design of process model element labels of seven business process modeling tools is summarized. These tools have been selected as they are a representative subset of the market leaders according to the 2010 Gartner Report [46]. Additionally, these tools provide sophisticated support for the process modeling phase as identified in [47]. At least one representative of widely used notations such as BPMN, EPC and Petri Nets has been investigated. The analysis results are summarized in Table 2.

Table 2. Results of business process modeling tool analysis.

Modeling Tool	Notation	Shape / Form	Size	Color	Orientation	Position	Segmentation
ARIS Business Architect	EPC	Calibri bold font, *changeable*	9 pt, *changeable*	black text on multiple backgrounds, *changeable*	centered, horizontal, *not changeable*	inside of element, *changeable*	restricted by element / label border
BizAgi Process Modeler	BPMN	Segoe UI plain font, *changeable*	8 pt, *changeable*	black text on multiple backgrounds, *changeable*	centered, horizontal, *not changeable*	inside activity, below event and gateway, *not changeable*	restricted by element / label border
BOC Adonis	BPMN	unknown plain font, *not changeable*	unknown, *not changeable*	black text on multiple backgrounds, *not changeable*	centered, horizontal, *not changeable*	inside activity, below event and gateway, *changeable*	restricted by element / label border
Horus Enterprise	Petri Net	Arial bold transition font, plain place font, *changeable*	18 pt transition label, 16 pt place label, *changeable*	black text on white background, *changeable*	left aligned, horizontal, *not changeable*	above transition, below place, *changeable*	no automatic segmentation, manual sizing of text label, segmentation on label border
Intalio Designer	BPMN	Verdana plain font, *changeable*	8 pt, *changeable*	black text on white or blue background, *changeable*	centered, horizontal, *not changeable*	inside activity, below event and gateway, *not changeable*	restricted by element / label border
Microsoft Visio 2013	BPMN / EPC	Calibri plain font, *changeable*	12 pt, *changeable*	black text on white background, *changeable*	centered, horizontal, *changeable (also rotation)*	inside activity and gateway, below event, inside element in EPC, *changeable*	restricted by element / label border
Signavio Process Editor	BPMN / EPC	unknown plain font, *not changeable*	unknown, *not changeable*	black text on white background, *partly changeable*	centered, horizontal, *not changeable*	inside activity, below event and gateway, inside element in EPC, *partly changeable*	restricted by element border

The analysis shows that these process modeling tools offer basic layouting support for process model element labels but do not provide any sophisticated label segmentation features. The tools typically provide users with options to adjust *shape and form* of model element labels, i.e. the font type and form can be changed. Also the *size and color* of labels can be modified in general. The standard text color is black while the background color of labels differs. The background color of labels outside a shape is typically white while it corresponds to the shapes' color if the label is placed inside a shape. With respect to the *orientation* of process model element labels the analyzed modeling tools do not provide such a rich feature set, which offers all possible options. While the alignment of labels can be changed, e.g. from the most common option 'centered' to 'left'- or 'right-aligned', the typical horizontal orientation can only be changed in Microsoft Visio. The implementation of *positioning* of element labels depends on the modeling notation. In general, most tools allow for a free positioning of labels. As a presetting, the BPMN modeling tools place the labels of an activity inside its shape, while the label of an event or gateway is typically placed below the shape. The EPC-based modeling tools place the labels inside the model elements and the Petri Net based modeling tool places them below places and above transitions. Finally, no sophisticated support for label *segmentation* is provided. For instance, no tool uses any approach to segment labels into chunks that might ease the understanding or reading fluency of a label. In general, all analyzed modeling tools wrap the words of a label as soon as the border of the corresponding shape or label form is reached - i.e. no words can poke out of their corresponding form. The Horus Enterprise tool does not apply an automatic segmentation leading to one-line labels. However, the label size can be segmented manually resulting in the same segmentation "behavior" as used in the other modeling tools.

To sum up, only rudimentary layouting is supported in existing modeling tools.

4 Recommendations for Visual Design in Literature

Next, we studied potential effects of each visual variable as described in literature. The analysis unveils that each visual variable can serve as a cognitive aid when used appropriately.

Shape/Form. The realization of this variable is achieved by choosing an appropriate letter type (uppercase, lowercase or mixed) and font type. Generally, a conventional and consistent usage of upper and lowercase letters is recommended (for the English language) [10]. However, the lowercase usage of letters is more promoted than uppercase. Tinker and Fisher [11, 12] showed that text displayed in uppercase suffers readability compared to text in lowercase. Text in lowercase is found to be read faster [13]. This result is explained by the unfamiliarity of the higher text size of uppercases for readers leading to higher reading difficulty. However, in case of low resolution uppercases might be advantageous [14]. Based on this consideration, an element label such as "Receive Order" should be transformed to "receive order" since upper cases are not common for both words. Process modelers presumably have more practice in reading lowercase words and letters should not distract attention from its neighboring letters in order to better form a coherence [13]. Research in the field of software comprehensibility has demonstrated that the identifier style camel-case (e.g., employeeName) is superior to the underscore style (e.g., employee_name). Although it took programmers higher visual effort to read camel-case identifiers, they performed better in a variety of experimental tasks when using camel-case [8]. This result gives a hint that uppercase might also have advantages when used for labels consisting of few words, which do not show in natural language prose reading. In practice, however, we can often find labels in which each word starts with an uppercase letter, e.g., [15].

With respect to font type, Verdana and Arial are considered to be the most legible fonts [16] (usage of sans-serif is recommended over serif). Readability is reduced when plain text is used instead of italicized [17]. Regarding text highlighting words in bold are not harder to read than non-bold words [18]. In the area of cartography [19, p. 642] states that "it is considered good practice to select one typeface, but allow several variants of a type family, e.g., allow Times Roman and italic, variation in weight (light, medium, bold), and a small number of font sizes." However, it is questionable whether it makes sense to transfer this practice to process modeling, since in process models lower variability than in maps is needed to distinguish between labels. Such a variation is not typically used for visualizing semantically different types of process elements. Consequently, we recommend a sans-serif, non-bold font text for process elements labels.

Size. Next, we turn to considerations for choosing an appropriate font size. The recommendation for reading text on software displays is 10 points (9 pixels) [16]. Moody [20] advocates the use of constant symbol size, symbol form and font size. Thus, he suggests to determine the optimal size of a symbol based on the amount of text that should fit inside (e.g., 2 × 3 cm as a size for symbols to be large enough to fit in labels of around 50 characters in 11-point font) [20]. The main argument behind this suggestion is that a variation in a visual variable (font size, symbol shape) may introduce the misunderstanding that the respective element is different to the other element, for instance of higher importance. The model reader might perceive the model element as significant or special although the variation is random due to a longer label and the model creator did not intend to communicate such a message. This reasoning is also reflected in labeling rules of other domains, which use variations in font size to indicate differences. For instance in the area of map labeling it is suggested that "larger cities should have their name in a larger font than smaller cities" [19, p. 642].

However, the optimal length for an element label is unclear and empirical evidence for the choice of 50 characters as maximum value is missing. Research in word recognition [21] has demonstrated that there is a u-shape relationship between word length (varying from 3 to 13 letters in the respective study) and word recognition. Words between 5 and 8 letters seem to be easiest to recognize, shorter words are skipped and longer words need more fixations. It may be possible that for process model element labels a similar medium label length is optimal. Yet, further research is needed to determine the "optimal" average label length.

Direction/Orientation. This variable is implemented through the alignment of the text label (e.g., horizontal vs. vertical, left-aligned vs. right-aligned). Agreement exists that a straight-on text orientation shows the best reading speed [22, 23]. Horizontal text is superior to vertical text [24]. In collaborative settings in which the (mobile) workbench is rotated between different users and thus the orientation is not directed towards all users, Wigdor and Balakrishnan [25] have shown that rotation does not impair readability as assumed in previous studies. Another aspect related to the visual variable direction is text alignment. An empirical study demonstrated that left-aligned text leads to higher task performance than justified text for web pages [26]. The word spacing that is forced by justified text was found to impair readability. It is open if a general warning for a justified alignment should be given for process element labels. While in the modeling notation BPMN a justified alignment is common, for Petri Nets typically left-aligned text labels are used.

Color. Color is a powerful and effective visual variable because it is detected in parallel by the human visual processing system [27]. Differences in color are perceived faster than differences in shape. Generally, color facilitates information processing [28], when used effectively. Readability is increased when colors with higher levels of contrast are used [29]. In the context of process modeling, empirical studies have demonstrated higher model comprehension when using color for syntax highlighting [30]. The prevailing color for text of process model element labels is black and the most widely-used font and background color combination is black text on a white background. Although a better performance was detected for other font/background color combinations, e.g., light blue on dark blue pages [29], we still advocate to use black text on a white background for modeling labels due to the higher familiarity with black on white.

Position. Generally, element labels can be positioned left, right, inside, above or below a process model element. Standard documents as BPMN [31] remain vague and give no clear recommendation for the label position. It is stated that "BPMN elements (e.g. Flow objects) MAY have labels (e.g., its name and/or other attributes) placed inside the shape, or above or below the shape, in any direction or location, depending on the preference of the modeler or modeling tool vendor." Based on cartography literature as e.g., [32], Moody [20] suggests the following positions for line labeling: close, but not behind a line, centered, above horizontal and to the right of vertical lines. Moody suggests placing labels centered in model shapes [20]. This is because, if labels are located within the label, the Gestalt law of common region is best exploited [33, 34]. The principle of common region is "the tendency for elements that lie within the same bounded area to be grouped together" [34, p. 312]. Thus, the reader can recognize without conscious effort which label belongs to which referent modeling element and the label-element association is non-ambiguous [20]. Therefore, labels should be placed spatially close to corresponding graphic objects (modeling symbols) to reduce cognitive resources needed for scanning and searching the model. This recommendation is also backed up by the 'spatial contiguity effect' [35], saying that students learn better when textual and graphical information belonging to each other are placed spatially close to each other.

Finally, the textual placement also depends on the length of the text and the node type. In the non-normative BPMN examples published by OMG [15], textual descriptions of the process element "activity" are typically positioned inside the elements while the descriptors of "event" elements (which usually have short descriptors) are positioned above or below. It is open whether long textual descriptions of process elements should be placed inside (which is common for BPMN) or outside the element.

To sum up, a placement spatially close to corresponding graphic objects is recommended.

Segmentation. An element label usually consists of several words that require an appropriate visual segmentation. Prior research on learning with text has demonstrated that text segmentation “facilitates the identification of meaningful units in the text” and improves text retention [36, p. 217]. In contrast to a process description in narrative text format, process models already break down the overall text into segments, as each label belongs to a specific business activity. Still, the segmentation on the lower level of words is relevant, too. A great deal of literature has already investigated whether phrase-cued text can help readers to improve reading performance resulting in mixed results [37]. In comparison to usual written text, which has no cues on phrase boundaries, phrase-cued text is typographically segmented into meaningful “chunks”, phrases or “units of thoughts” e.g., by printing spaces between phrases or using line breaks. Negative consequences of wrongly placed line breaks can result from the ‘immediacy assumption’ in text reading, which assumes that the “reader tries to interpret each content word of a text as it is encountered, even at the expense of making guesses that sometimes turn out to be wrong” [38, p. 330]. Additionally, appropriate text segmentation has an influence on reading fluency. [40] showed that when English phrases are interrupted by a line break, readjustment to non-anticipated words in the next line is especially harder for non-native English speakers. Thus, text should be formatted (e.g., by line breaks) in a way that avoids phrase-disrupting and preserves clausal units in order to promote reading fluency [39]. Therefore, a goal in setting line breaks should be to “help readers avoid incorrect anticipation, while also considering those moments in the text where readers tend to pause in order to integrate the meaning of a phrase” [40, p. 720]. This visual variable has been widely neglected. Empirical evidence is missing how to best segment a text label.

5 Discussion

Based on the analysis of both perspectives (literature and modeling tools) we identify areas for future research and potential improvement of existing tools as follows. Table 3 summarizes our discussion on visual design of process element labels. It indicates which recommendations from literature on informational graphics can be adopted for process element labels and for which visual variables no appropriate recommendations could be found and a validation is outstanding.

Specifically, a deeper understanding of the characteristics size and direction/orientation is needed in order to support an appropriate perception of the process elements. In addition, the research to date has not yet addressed “segmentation” in a way relevant to the context of process model labels. A solution to an appropriate segmentation of text labels into chunks is essential since it highly impacts the lexical access (activation of the meanings of a language) of the label. If the lexical access is hampered, readers cannot understand the process model element label and thus an inappropriate association of the real process might arise. With respect to the tool support, on the one hand some variables are already widely implemented as e.g., options for changing font type and size or text alignment. On the other hand label segmentation is neglected and only implemented rudimentary. What might also be a nice-to-have feature of process modeling tools is an automatic conversion of letters from lower- to uppercase and vice versa. This functionality was not found in any tool.

Table 3. Recommendations for the visual design of process model element labels

Visual variable	Recommendation
Shape/form	Lowercase usage of letters, sans-serif, non-bold fonts
Size	Words between 5 to 8 letters seem to be easiest to recognize; "optimal" average length is an open research issue
Direction/orientation	Left-alignment is superior, but has not been empirically validated for process element labels
Color	Usage of high levels of contrast for font/background colors
Position	Placement spatially close to corresponding graphic objects
Segmentation	Open issue

6 Related Work

The visualization of process element labels impacts the understandability of a business process model. Therefore, related approaches are those, which intend to improve process model understandability. Two complementary streams of research related to this goal can be found. The first one deals with improving the visual design of process modelling languages and "secondary" language issues of process models. Prior research in this vein has for instance compared different languages and symbol choices [41] or suggested improvements to visual syntax [42]. However, available studies have addressed label design only as a side issue.

The second research stream relevant to this paper focusses on improving semantics of process model labels. In this context, prior research has put a specific focus on improving the fit between the actual semantic interpretation of process model labels and their intended meaning [7]. For instance, the semantic quality of element labels can be promoted through a controlled assistance for labeling of process model elements [44, 45] and recommending superior naming conventions [4].

All these works, however, do not consider the visual design of the process model element label. Therefore, to the best of our knowledge, no theoretical or empirical work investigating the visual design of element labels have so far been undertaken. Findings from disciplines where visual word recognition is central such as graph drawing, cartography and linguistics can be adopted to process element label visualization. These related approaches have been discussed in Sect. 4.

7 Summary and Outlook

To sum up, this paper has presented the first discussion of theoretical issues of the visual design of process model element labels. The paper integrated relevant research findings of multiple disciplines concerned with efficient presentation of text labels to identify a cumulative body of label layout-related knowledge. Recommendations for font, size and color can be transferred to labels of process model elements, while identification of appropriate recommendations for size (label length), direction/ orientation, position and segmentation is still an open research goal.

In addition, we investigated the as-is situation of visual design support in common process modeling tools indicating only little support for automatic layouting and fine tuning of labels. We advise future tool revisions to take visual variables for process model element labels into account. Furthermore, we suggest extending related modeling guidelines with relevant aspects on visual design of labels. This research has thrown up many questions in need of further investigation. Considerably more work will need to be done to define heuristics for the visual design of labels for all common labeling styles in our future research effort. In addition, we encourage empirical research to investigate the actual effects of label design on human understanding.

References

1. Moody, D.L.: The "physics" of notations: towards a scientific basis for constructing visual notations in software engineering. IEEE Trans. Software Eng. **35**, 756–779 (2009)
2. Christensen, J., Marks, J., Shieber, S.: An empirical study of algorithms for point-feature label placement. ACM Trans. Graph. (TOG) **14**, 203–232 (1995)
3. Wagner, F., Wolff, A., Kapoor, V., Strijk, T.: Three rules suffice for good label placement. Algorithmica **30**, 334–349 (2001)
4. Mendling, J., Reijers, H.A., Recker, J.: Activity labeling in process modeling: empirical insights and recommendations. Inf. Syst. **35**, 467–482 (2010)
5. Leopold, H., Smirnov, S., Mendling, J.: On the refactoring of activity labels in business process models. Inf. Syst. **37**, 443–459 (2012)
6. Leopold, H., Eid-Sabbagh, R.-H., Mendling, J., Azevedo, L.G., Baião, F.A.: Detection of naming convention violations in process models for different languages. Decis. Support Syst. **56**, 310–325 (2013)
7. Koschmider, A., Ullrich, M., Heine, A., Oberweis, A.: Revising the vocabulary of business process element labels. In: Zdravkovic, J., Kirikova, M., Johannesson, P. (eds.) CAiSE 2015. LNCS, vol. 9097, pp. 69–83. Springer, Heidelberg (2015)
8. Binkley, D., Davis, M., Lawrie, D., Maletic, J.I., Morrell, C., Sharif, B.: The impact of identifier style on effort and comprehension. Empirical Softw. Eng. **18**, 219–276 (2013)
9. Deeb, R., Ooms, K., De Maeyer, P.: Typography in the eyes of Bertin, gender and expertise variation. Cartographic J. **49**, 176–185 (2012)
10. Moody, D.L., Sindre, G., Brasethvik, T., Sølvberg, A.: Evaluating the quality of process models: empirical testing of a quality framework. In: Spaccapietra, S., March, S.T., Kambayashi, Y. (eds.) ER 2002. LNCS, vol. 2503, pp. 380–396. Springer, Heidelberg (2002)
11. Tinker, M.A.: Legibility of Print. Iowa State University Press, Ames (1963)
12. Fisher, D.F.: Reading and visual search. Mem. Cogn. **3**, 188–196 (1975)
13. Sanocki, T., Dyson, M.C.: Letter processing and font information during reading: beyond distinctiveness, where vision meets design. Atten. Percept. Psychophys. **74**, 132–145 (2012)
14. Arditi, A., Cho, J.: Letter case and text legibility in normal and low vision. Vision. Res. **47**, 2499–2505 (2007)

15. Object Management Group: BPMN 2.0 by Example (2010)
16. Sheedy, J.E., Subbaram, M.V., Zimmerman, A.B., Hayes, J.R.: Text legibility and the letter superiority effect. Hum. Factors J. Hum. Factors Ergon. Soc. **47**, 797–815 (2005)
17. Hill, A., Scharff, L.: Readability of websites with various foreground/background color combinations, font types and word styles. In: Proceedings of 11th National Conference in Undergraduate Research, pp. 742–746 (1997)
18. Tullis, T.S., Boynton, J.L., Hersh, H.: Readability of fonts in the windows environment. In: Conference Companion on Human Factors in Computing Systems, pp. 127–128. ACM (1995)
19. Dijk, S.V., Kreveld, M.V., Strijk, T., Wolff, A.: Towards an evaluation of quality for names placement methods. Int. J. Geogr. Inf. Sci. **16**, 641–661 (2002)
20. Moody, D.L.: The art (and science) of diagramming: communicating effectively using diagrams (tutorial). In: IEEE Symposium on Visual Languages and Human-Centric Computing. IEEE (2012)
21. New, B.: Reexamining the word length effect in visual word recognition: new evidence from the English Lexicon Project. Psychon. Bull. Rev. **13**, 45–52 (2006)
22. Kruger, R., Carpendale, S., Scott, S.D., Greenberg, S.: How people use orientation on tables: comprehension, coordination and communication. In: Proceedings of the 2003 International ACM SIGGROUP Conference on Supporting Group Work, pp. 369–378. ACM (2003)
23. Tang, J.C.: Findings from observational studies of collaborative work. Int. J. Man Mach. Stud. **34**, 143–160 (1991)
24. Yu, D., Park, H., Gerold, D., Legge, G.E.: Comparing reading speed for horizontal and vertical English text. J. Vis. **10**, 21 (2010)
25. Wigdor, D., Balakrishnan, R.: Empirical investigation into the effect of orientation on text readability in tabletop displays. In: Gellersen, H., Schmidt, K., Beaudouin-Lafon, M., Mackay, W. (eds.) ECSCW 2005, pp. 205–224. Springer, Heidelberg (2005)
26. Ling, J., van Schaik, P.: The influence of line spacing and text alignment on visual search of web pages. Displays **28**, 60–67 (2007)
27. Treisman, A., Souther, J.: Illusory words: The roles of attention and of top–down constraints in conjoining letters to form words. JExPH **12**, 3 (1986)
28. Lohse, G.L.: A cognitive model for understanding graphical perception. Hum.-Comput. Interact. **8**, 353–388 (1993)
29. Hall, R.H., Hanna, P.: The impact of web page text-background colour combinations on readability, retention, aesthetics and behavioural intention. Behav. Inf. Technol. **23**, 183–195 (2004)
30. Reijers, H.A., Freytag, T., Mendling, J., Eckleder, A.: Syntax highlighting in business process models. Decis. Support Syst. **51**, 339–349 (2011)
31. Object Management Group: Business Process Model and Notation (BPMN) Version 2.0.2 (2013)
32. Imhof, E.: Positioning names on maps. Am. Cartographer **2**, 128–144 (1975)
33. Palmer, S.E.: Common region: a new principle of perceptual grouping. Cogn. Psychol. **24**, 436–447 (1992)
34. Palmer, S.E., Brooks, J.L., Nelson, R.: When does grouping happen? Acta Psychol. **114**, 311–330 (2003)
35. Mayer, R.E., Moreno, R.: Nine ways to reduce cognitive load in multimedia learning. Educ. Psychol. **38**, 43–52 (2003)
36. Florax, M., Ploetzner, R.: What contributes to the split-attention effect? The role of text segmentation, picture labelling, and spatial proximity. Learn. Instr. **20**, 216–224 (2010)

37. Rasinski, T.V.: The effects of cued phrase boundaries on reading performance: a review (1990)
38. Just, M.A., Carpenter, P.A.: A theory of reading: from eye fixations to comprehension. Psychol. Rev. **87**, 329 (1980)
39. Levasser, V., Macaruso, P., Palumbo, L.C., Shankweiler, D.: Syntactically cued text facilitates oral reading fluency in developing readers. APsy **27**, 423–445 (2006)
40. Salama, A., Oflazer, K., Hagan, S.: Typesetting for improved readability using lexical and syntactic information. In: Proceedings of the 51st Annual Meeting of the Association for Computational Linguistics, pp. 719–724 (2013)
41. Figl, K., Mendling, J., Strembeck, M.: The influence of notational deficiencies on process model comprehension. J. Assoc. Inf. Syst. **14**, 312–338 (2013)
42. Genon, N., Heymans, P., Amyot, D.: Analysing the Cognitive Effectiveness of the BPMN 2.0 Visual Notation. In: Malloy, B., Staab, S., Brand, M. (eds.) SLE 2010. LNCS, vol. 6563, pp. 377–396. Springer, Heidelberg (2011)
43. La Rosa, M., Wohed, P., Mendling, J., ter Hofstede, A.H.M., Reijers, H.A., van der Aalst, W.M.P.: Managing process model complexity via abstract syntax modifications. IEEE Trans. Industr. Inf. **7**, 614–629 (2011)
44. Leopold, H., Mendling, J., Reijers, H.A., La Rosa, M.: Simplifying process model abstraction: techniques for generating model names. Inf. Syst. **39**, 134–151 (2014)
45. Delfmann, P., Herwig, S., Lis, L., Stein, A.: Supporting distributed conceptual modelling through naming conventions-a tool-based linguistic approach. Enterp. Model. Inf. Syst. Architect. **4**, 3–19 (2009)
46. Sinur, J., Hill, J.B.: Magic quadrant for business process management suites. Technical report, Gartner RAS Core Research (2010)
47. Koschmider, A., Fellmann, M., Schoknecht, A., Oberweis, A.: Analysis of process model reuse: where are we now, where should we go from here? Decis. Support Syst. **66**, 9–19 (2014)