Reading Business Process Models the more Expert Way

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Abstract. Business process models represent complex visual graphics, which often require training and expertise to be read and interpreted appropriately. As experts in this domain have a perceptual advantage based on a higher visual span and access to complex schemas in long-term memory, they faster reach task-relevant information and avoid task-redundant focusing on task-irrelevant information. In business process modeling, visual cues are used to guide readers to relevant information. However, visual cues are often not based on what we know about how experts read visual graphics. Therefore, we review eye-tracking and think-aloud studies for visual graphics and business process models to describe expert strategies when reading business process models. Based on these strategies, we derive implications that will support novices to obtain a more expert view when reading business process models. Our suggestions include different segmentation needs and how experts' reading strategies can be integrated into visual cueing strategies.

Keywords: Business Process Modeling, Expertise, Eye-Tracking, Think-aloud.

1 Introduction

Business professionals use diverse representational forms to describe their processes ranging from textual [1] and semi-structured textual description [2] to more graphical representations using modeling grammars such as the Business Process Modeling and Notation (BPMN) or the Event-driven Process Chain (EPC). Out of these representational forms, business process model readers prefer the more graphical representation based on modeling grammars [3]. This seems surprising, as for visual programming, [4,5] found that we faster understand text than graphical representations. Yet, graphical representations are more appealing. They are richer than text, make structure visible, provide a higher level of abstraction, and are more fun [6].

However, understanding graphical business process models (hereafter referred to as business process models) requires expertise. Understanding these models depends on intensity of prior work with these models (method expertise) and with the domain treated in the model (domain expertise). In most cases, model readers are not method experts and in some cases not even domain experts. For example, business process models are often used for business process documentation [7], which new employees use as introduction to the domain. As method and domain novices, these employees have problems understanding these introductions.

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Why expertise is required for understanding graphical representations is discussed by Petre in [6]. She argues that it is not obvious for model readers where to start looking at in graphical representations. Readers rather choose between different strategies to access the representation. These strategies influence, which meaning is read out of it. If they choose a different strategy, they might face a different meaning. Petre further argues that expertise influences on the strategies readers use to read a graphical representation. Indeed, experts use more effective strategies than novices and tend to stick to their strategy [8]. After experts take a practice trial to identify an appropriate strategy for a certain task, they stick to this strategy for similar tasks. In contrast, novices often vary their strategy and sometimes even change it during the task [8]. Novices further suffer from misreading, a lack of knowledge to identify relevant information, and a feeling to not be reading thoroughly enough. As a result, they have to reread the graphical representation over and over again [6].

Visual cueing is discussed to direct the novices' gaze to those parts that their authors deemed relevant for understanding [9,10]. That way, colour is used to highlight gateways (e. g. [9,11]) or to highlight subflows of business process models (e. g. [10,12]). Yet, visual cuing is not based on what we know about how experts read graphical representations in general and business process model in particular. Hence, it can be questioned whether they are effective to give novices a more expert reading strategy. In search for an answer, we first summarize experts' reading strategies in graphical representations and in business process models. Our focus is on procedural business process models. Based on these strategies we discuss implications for model readers and further assess whether current visual cuing strategies allow to give novices a more expert view when reading business process models. To summarise the experts' reading strategies in graphical representations, we focus on eye-tracking evidence for two reasons: First, eye movement behaviour has been studied for various domains of expertise, such as chess, medicine, art and aviation [13,14]. Second, expertise rather relies on procedural knowledge (knowing how) than on declarative knowledge (knowing what). Since it is rather difficult to access procedural knowledge, eye-tracking provides a method that allows to make this information more explicit [13]. For business process modeling, we further include think-aloud studies as we aim to describe prior research more complete. We do not include prior empirical findings that do neither include eye-tracking nor think-aloud as we focus on the reading process and this process cannot easily be assessed without eye-tracking or think-aloud While the next section summarizes eye-tracking evidence of visual expertise, section 3 reviews eye-tracking and think-aloud evidence for expertise in reading business process models. In section 4, we derive implications for business process modeling and finish with a conclusion in section 5.

2 Eye-tracking evidence of visual expertise

Eye-tracking has often been used in the domains of chess and medicine to describe expertise [13]. As research of these two domains contributed almost without any cross citations, Reingold and Sheridan have integrated their results within a review in [13].

In [14] eye-tracking results from further domains are integrated in a meta-analysis. We use this study to back up results from chess and medicine. Reingold and Sheridan summarize that the global processing advantage, which is often attributed to expertise in medicine [13], is in line with what researchers call perceptual advantage in chess [15]. In medicine, the global processing advantage is explained with the global-focal search model [16] and the two-stage detection model [17]. According to the global-focal search model, experts gain an overall impression when comparing content of graphical representations with internal schemas, leading their gaze to most important areas for problem solving. The two-stage detection model describes that experts initially filter regions that are required for further evaluations. Hence, in both models the authors assume that experts in medicine first scan the global patterns when reading graphical representations. For the chess domain, eye-tracking revealed that experts are even unable to avoid processing the global pattern no matter if it is supportive or detrimental to task performance [18,19]. Gegenfurtner et al. provide evidence for further domains for the holistic model of image perception, which proposes experts to start with an initial global analysis [14]. Hence, across several domains, experts use their perceptual advantage for processing the global pattern first. Yet, why do experts in contrast to novices have a perceptual advantage?

With growing expertise, associations are developed between groups of information that form complex schemas in long-term memory (LTM) [20]. While experts have developed complex schemas, novices often require several schemas to cover the same information. Beyond having complex schemas, expertise is characterized with having many schemas available. An initial estimation of the number of the experts' schemas amounts up to 50.000 [20] and was recently corrected to 300.000,00 [21]. Schemas are further distinguished in chunks and templates. While chunks only cover fix information, templates are more flexible as they also include variable information. Stark et al. have discussed possible chunks and templates for business process modeling [12]. For example, BPMN intermediates and experts might have a template for gateway and use the variables +, o or empty to specify the type of gateway into exclusive, inclusive or parallel. In contrast, novices only have chunks available and might need three different chunks to cover the same information (see fig. 1c-d).

When reading business process models, readers tend to fixate a certain part of the model (fig. 1a), which is then reflected as an iconic representation in working memory (WM) [22]. Based on this representation, WM creates pointers to the schemas stored in LTM [22]. In 1956, Miller estimated the number of pointers to be around 7+/- 2 [23], and Cowan, recently, limited this number to around 4 [24]. Taking 7 as a basis, Stark et al. exemplarily showed that experts would only need 3 pointers to reason about what is fixated while novices would require more than 7 pointers [12] (fig. 1b). Assuming that it is true that experts have access to more complex schemas than novices, Reingold and Sheridan conclude that experts' and novices' fixations must differ in length and location [13]. Based on the amount of information that readers perceive from a fixation, their fixation point varies [13]. While novices rather fixate single objects, experts locate their fixations to maximize the information gain, for instance in between objects. In fact, there is evidence that chess experts rather fixate along the edges of squares [25] or on empty squares [26] while novices tend to fixate figures. For further domains, Gegenfurtner et al. provide evidence for the theory of long-term working memory [14]. In line with schema theory, this theory assumes that expertise allows to extend the capacity of WM as more complex retrieval structures are available [27]. This is why, Gegenfurtner et al. predicted that experts have shorter fixation durations and showed in their experiments that experts had slightly shorter fixation durations than novices [14].

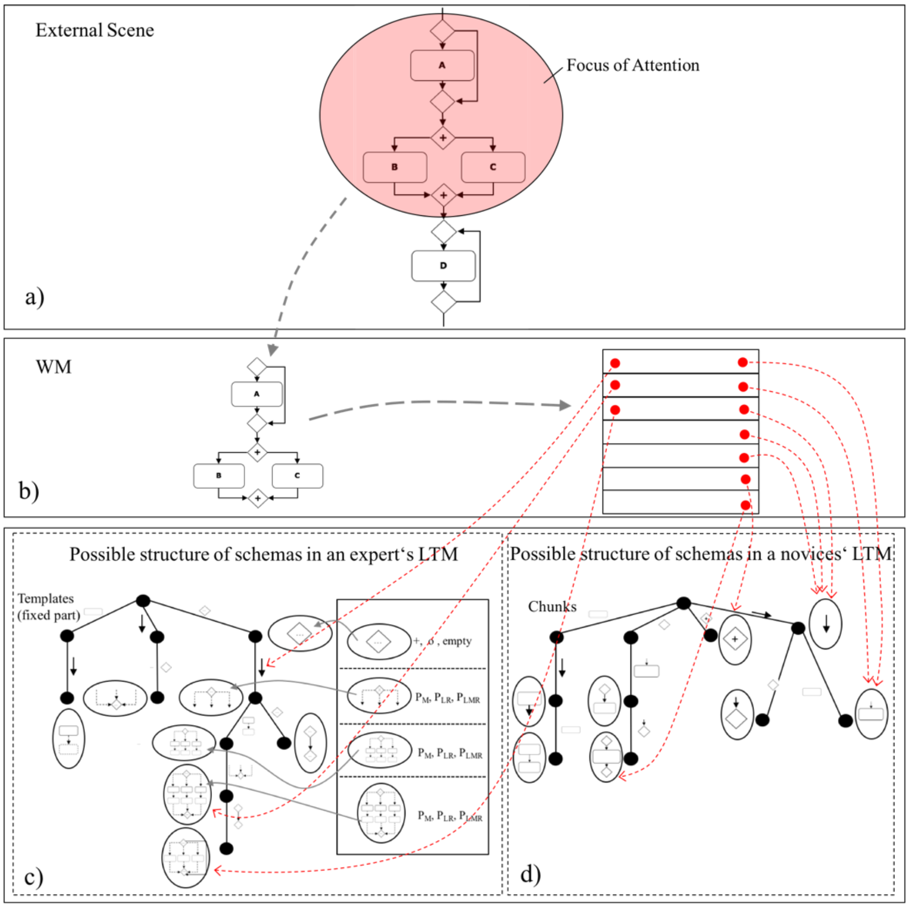

Figure 1. Integrating schemas into the reasoning process on the basis of [12]

Experts do not only extend limitations of WM. They also perceive more domain-related information from a fixation as they have a large visual span. In contrast to novices, experts also use parafoveal and peripheral vision to detect information [13]. For chess, evidence for the expert's larger visual span is reported in [15]. In line with this research, Carmody et al. showed that under brief exposure conditions, which preclude further eye-movements, expert radiologists detected nodules that were 15 degrees away while less experienced persons only detected nodules that were 10 degrees away [28]. Also in other domains, experts detect information without bringing it into the fovea [14]. As a consequence, experts perceive (including foveal, parafoveal and peripheral vision) and process (accessing complex schemas in LTM) more information within a single fixation. These advantage allow experts to first scan the global pattern in complex representations.

Experts' behaviour to first scan the global pattern has been used to explain why experts are able to rather fixate task-relevant objects and to arrive faster at these objects than novices. For the chess domain, Charness et al. showed that when experts fixate figures these figures are to a greater proportion task relevant than those of intermediates [29]. Also for radiology, there is evidence that experts spend a greater proportion of time fixated on abnormalities [30,31] and arrive at the abnormalities faster [32,33]. Gegenfurtner et al. showed for further domains that experts have more fixations on task-relevant areas than novices [14]. When scanning the global patterns, experts benefit from free viewing conditions [34]. Yet, when segmenting their global perspective, a decrease in accuracy was found [35]. To sum up, experts are able to process the global patterns first, which helps them to faster arrive at task-relevant information. Yet, how experts process the global patterns differs among the domains. Skills that make an expert in one domain might not be transferred to others [36], which is why expertise needs to be considered for the domain.

3 Eye-tracking evidence of visual expertise

Reading business process models has been analysed for error detection and understanding with think-aloud and eye-tracking (see table 1). For error detection, subjects were asked to identify possible errors. While error detection tasks were rather similar, understanding tasks varied. For example, Petrusel et al. used a sequential procedure by asking specific questions about the model and continued with further questions after the subject provided an answer [9,37]. In contrast, Haisjackl et al. used open questions, where subjects had to describe how they read the model [38,39].

Table 1. Previous eye-tracking and think-aloud studies on reading business process models

Lit.	*Tasks*	*Participants*	*Focus*	*Method*
[38]	Under-standing	9 intermediate experts	Reading strategies in declarative process models	Think-aloud
[39]	Under-standing	18 intermediate experts	Follow-up study of [38]	Think-aloud
[40]	Error detection	12 intermediate experts	Error detection in models that differ in complexity	Think-aloud
[41]	Error detection	12 experts	Reasoning in multiple diagrams	Think-aloud
[42]	Under-standing	26 experts	Relevance of Relevant Region	Eye-tracking
[9]	Under-	75 experts and int.	Colouring elements of the	Eye-

	standing	experts	Relevant Region	tracking
[37]	Under-standing	75 experts and int. experts	Visual Cognition Efficiency and Intensity	Eye-tracking
[43]	Under-standing	29 novices and experts	Infl. of layout quality on novices' and experts' reading strategy	Eye-tracking

For error detection, reading strategies have been assessed in multiple diagrams [41] and in single diagrams [40]. Hungerford et al. used think-aloud to assess reading strategies in multiple diagrams including Data Flow Diagrams (DFDs), ERDs and a Statement of Problems [41]. They found subjects switched attention between the design documents. While doing this, some subjects used a fast-switching behaviour with a focus for short periods on one and quick switches to other models while other subjects first focussed the DFD and then switched to the ERD replicating this behaviour up to three times [41]. As the fast-switching behaviour was most effective, the authors suggest that search effectiveness can be increased if personal is employed that fast switches between diagrams [41].

Haisjackl et al. focussed on reading strategies in single diagrams with different complexity [40]. They identified three reading strategies: Getting an overview (which is in line with first scanning the global pattern), directly starting to read the model, and creating a mental list of possible errors. For the less complex model, about 58% of the subjects first got an overview, 17% first created a mental list of possible errors and 25% started reading directly. For more complex models, a part of the subjects that directly started to read the model switched to first getting an overview. Subjects that used the other two strategies, sticked to their strategy. Haisjackl et al. further describe the strategy of first getting an overview as reading pool and lane descriptions, reading through the whole model, or analysing the structure of the model [40].

For understanding tasks, Petrusel et al. define a relevant region as an area that model readers require to analyse for solving their task [42]. Investigating this region in an eye-tracking experiment, they found that experts make more fixations on elements of the relevant regions than on other elements, spent a higher percentage of time fixated on relevant regions than on other regions, and give more correct answers when showing higher shares of fixations on relevant regions. Continuing this research by colouring elements of the relevant region that are crucial to solve a specific task, Petrusel et al. found that colouring helps to decrease the total duration of fixation, to reduce time and to improve efficiency [9]. We remark that Petrusel et al. change the natural reading strategy by highlighting the relevant region as task-specific elements pop-out in the model. Yet, with their research they succeed in introducing the relevant region, which is important when discussing how processing the global pattern might faster lead to fixating task-relevant information for our domain. The relevant region might further be used to empirically assess if processing the global patterns helps to faster reach task-relevant information in business process modeling.

Like highlighting elements of the relevant region, also the quality of layout induces changes of the reading strategies as shown by Störrle et al. in [43]. The authors asked novice and expert subjects to answer specific understanding questions for different kinds of UML diagrams varying good and bad layout. They identified three patterns including [43]: (i) Branch following from anchor (BFFA), which means that an anchor is established (top left corner, largest element, or centre) and subjects started reading from there according to the graph structure, (ii) Left/Right Top/Bottom (LRTB), which means that subjects started at the top-left corner and proceed downwards or to the right irrespective of the arrow direction, and (iii) Random Walk (RW), which means that no discernable pattern was detected. The authors found that for diagrams with a good layout, experts and novices followed BFFA or LRTB, while for diagrams with a bad layout, novices tended to use RW while experts continued using BFFA/LRTB. To their surprise these results were obtained irrespectively of the diagram type. The authors suggest that increasing the number of elements and the number of layout flaws have a similar effect on cognitive processing. Yet, the number of flaws might be reduced, while the number of elements need to be the same to cover the information that has to be conveyed.

For understanding tasks, Haisjackl et al. further use think-aloud to assess the reasoning process in declare models [38,39]. In contrast to procedural process models, declare models specify the interplay of process actions and are typically not sequential [39]. Although we focus on procedural business process models, we decided to integrate this research as Haisjackl et al. found insights for procedural business process models. In particular, they found that subjects followed an iterative and sequential way of reading the models although sequential information was not given [38]. They further describe the reading-routine: Readers first skim over the model to find an entry point. Having found one, they define, in which order the activities are executed. This routine is then repeated for parts of the model that are not connected. Their results might be interpreted that subjects with expertise in business process modeling and intermediate expertise in declarative process modeling might rather have access to LTM-schemas that reflect sequential process modeling patterns. Their behaviour to follow a sequential way of reading declarative process modeling patterns, might be explained as a search to match their LTM-patterns, which can rather be characterized as sequential than declarative. This is also in line with the authors' interpretation that subjects tend to prefer this kind of information [39]. Having summarized how experts read business process models, we further discuss implication on segmentation and for visual cuing.

4 Implications for Business Process Modeling

As discussed in [43], the quality of layout can change the reading strategy. Störrle et al. have suggested that in particular, novices might suffer from a bad layout and switch to a less appropriate reading strategy while experts are more resistant to a bad layout and rather stick to their reading strategy. Apart from layout, also hierarchy might change the reading strategy as the natural flow of the process model needs to be interrupted when integrating sub-processes into the parent-process. As discussed for layout, how hierarchy impacts might depend on the degree of expertise. In section 2 we have discussed that when segmenting the expert's view, a decrease of accuracy is reported [35]. In line with this results, Hungerford et al. show that problem solving in multiple diagrams occurs most efficiently with the fast-switching strategy [41]. Using this strategy, experts produce unsegmented viewing conditions in a segmented environment and can hence, fully exploit their perceptual advantage. Accordingly, experts might benefit from flat models as they can perceive a lot of information from a fixation without having to switch fast between diagrams and might also benefit from hierarchy in case they can perceive sub- and parent-processes together and thus, use a fast-switching behaviour. Hungerford et al. conclude that search effectiveness can be increased if personal is employed that uses the fast-switching strategy or if personal is trained to use it [41]. We think this seems a valid conclusion for experts but not for novices. Novices do neither have a large visual span nor access to complex domain-related LTM-schemas, which is why their WM is still limited and precludes the processing of complex global patterns and a consequent focus on task-relevant information. Hence, novices might not profit from fast-switching as they cannot perceptually encode the total amount information. As novices might not use fast-switching to perceive and process sub- and parent-process information efficiently, we suggest that they would rather not profit from hierarchy. This suggestion is in line with results from [44], who found that novices rather benefit from flat than hierarchical business process models.

Visual cuing is discussed to increase the novices' understanding. Several visual cuing strategies have been developed (e. g. [9-12],[37]) to highlight those elements that their authors deemed important for understanding. We assess if these strategies focus on those elements that experts fixate on when scanning the global patterns, to further discuss if these strategies might be used to allow novices a more expert reading strategy. To our knowledge visual cuing strategies are so far only discussed for understanding tasks, which is why we also focus on understanding. As described for specific understanding tasks, experts at some point of the reading process seem to detect the relevant region [9,42]. Yet, how do experts detect this region? Haisjackl et al. describe that subjects skim over the model for an entry point and then follow the sequential order [38,39]. Skimming over the model is further specified in [40] with creating a mental list, getting an overview, and directly starting to read the model. While creating a mental list is specific for error detection, getting an overview and directly starting to read the model can also be applied to understanding tasks. Out of these two strategies, Haisjackl et al. argue that, in particular, getting an overview is connected to expertise and specify this strategy into reading pool and lane descriptions, reading through the whole model, or analysing the structure of the model. While the strategy of reading through the whole model does not tell what particular elements experts focus on when processing the global pattern, pools and lanes as well as structure of the model are more concrete. Using this specification, we argue that pools and lanes as well as the structure of the model might be important when scanning the global pattern to further identify the relevant region.

Highlighting these elements is in line with results from Stark et al. in [10, 45], who conducted a content analysis, to find elements that readers need to identify for solving understanding tasks. According to [45], model readers first scan the whole model for some elements before they continue locally, which is why the authors distinguished in global and local search for ERD-understanding tasks. Accordingly, ERD-readers scan the whole model for particular elements such as entity-types (global search) and continue scanning further elements around previously identified entity-types (local search). For business process modeling, Stark et al. identified tasks and pools / lanes as important for global searches. They further discussed that the process flow is rather used for local searches as for most tasks, model readers first search for two or more tasks and than continue to analyse the process flow in relation with these tasks. Nonetheless, the process flow is present throughout the whole model and some questions might require the model reader to include parts of the process flow before and after two tasks (for example in case of iterations) or to only analyse the process flow, which is why we suggest the process flow to be important also on a global level. As this is in line with Haisjackl et al., who also specified getting in overview with reading the structure of the model in [40], we suggest that also the process flow should be highlighted when using visual cues. Summarizing this discussion, we argue that process flow as well as pools and lanes might be most important to process the global patterns. Highlighting process flow and pools- and lanes, we might direct the novices' attention to the global patterns. In the following we assess whether current visual cuing strategies integrate these elements.

Visual cuing strategies have so far been used for different elements. The process flow has been highlighted by highlighting gateways [9,11,37,46] and subflows [10-12]. For highlighting gateways we can further distinguish visual cuing into task-specific and task-generic. Petrusel et al. show that task-specific highlighting can lead to increased comrehension performance [9,37] (see fig. 2). In contrast, Reijers et al. in [11] and Kummer et al. in [46] have discussed design decisions that are not task-specific. Reijers et al. coloured matching gateways and found support for novices' comprehension accuracy [11]. Kummer et al. derived different visual cuing strategies for the germanic and confucian cultural context [46] assuming that for a confucian background more intensive colours can be used than for a germanic background. In contrast, to highlight the process flow via its gateways, Stark et al. highlighted the process flow by visually distinguishing subflows [10,12]. The authors derive a visual cuing strategy that highlights gateways and boundaries of subflows (e. g. parallel or alternative subflow) and found support for the novices' comprehension efficiency in [12]. Their visual cuing strategy of [12] was further developed in [10] for the dimension of colour harmony. Table 2 summarizes the elements that are focussed on in current visual cuing strategies and contrasts these elements with those identified as important to scan the global patterns. We suggest that the design decision in [10] covers elements that are discussed as important to allow novices to first fixate those elements that experts focus on when processing the global pattern. Yet, to our knowledge effects on understanding based on highlighting gateways and subflows have not yet been contrasted, which is why also highlighting gateways (e. g. [11]) with further highlighting pools and lands might be successful to direct the novices gaze to those part that experts fixate on when first scanning the global pattern.

We further remark that prior eye-tracking and think-aloud findings of reading business process models relate to models that were usually presented from left to right. Figl and Strembeck have assessed the influence of flow direction in a pilot experiment in [47] and found no significance evidence for models for a superiority of the left-to-right flow direction and cautiously suggest that model readers might adapt also to uncommon reading directions. On this basis, we might suggest that discussed implications might also be useful for models using other reading directions.

Table 2. Covering elements for scanning the global pattern for recent visual cuing strategies

Lit.	*Scope of highlighting*	*Process Flow*	*Pools, Lanes*
[11]	Task-generic matching gateways	X	
[9],[37]	Task-specific relevant elements within the relevant region	X	
[12]	Task-generic process flows	X	
[10]	Task-generic process flow, lanes and tasks.	X	X
[46]	Task-generic highlighting for different cultural backgrounds	X	

5 Conclusion

Our analysis yielded that experts across several domains first process the global patterns, thereby focusing on task-relevant while largely neglecting task-irrelevant information. Experts can use this behaviour as they have developed a perceptual advantage, which bases on their vast visual span and their access to complex domain-related LTM-schemas. We have further specified how experts process the global patterns in business process models by reviewing think-aloud and eye-tracking experiments. Based on the literature we summarise that in business process modeling, experts process the global pattern by focussing on the process flow as well as pools and lanes. We have further discussed that experts, in contrast to novices, might rather profit from segmentation, when presenting hierarchy so that parent- and sub-processes can be perceived together. We have further assessed wether visual cuing strategies can be used to guide the novices' gaze to those elements that experts scan when processing the global patterns. We suggest that the strategies to highlight subflows and pools and lanes as discussed in [12] or the strategy to highlight gateways as discussed in [11] with highlighting pools and lanes might be suited to guide the novices' gaze to those elements that experts fixate on when scanning the global patterns. For future research we suggest to further integrate expertise into segmentation research as experts might have different segmenation needs that novices. We further suggest that current visual cueing strategies need to be investigated with eye-tracking to further show if first fixations of novices approach the early fixations of experts, when using visual cues.

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