

## **Presentation format and syllogistic reasoning**

Orlando Espino\* and Carlos Santamaría

*Universidad de La Laguna (Spain)*

Figural effect is a response bias that depends on the arrangement of the terms in syllogisms. The usual pattern in construction tasks is that participants tend to give A-C responses when the syllogisms are in figure 4(A-B/B-C), while the majority of their conclusions are in the opposite direction (C-A) for syllogisms in figure 1 (B-A/C-B). We report on one experiment that examines the role of the presentation format of premises (two-line presentation vs. one-line presentation) in categorical syllogisms. The experiment showed that when premises were presented in one-line presentation format, participants generated more A-C than C-A conclusions in all syllogistic figures. However, when premises were presented in two-line presentation format, participants generated more A-C conclusions in figure 4 and more C-A conclusions in figure 1, while there were no reliable differences for either figure 2 (A-B/C-B) or figure 3(B-A/B-C). We discuss the implications of these results for different theories of reasoning.

Logic problems are often presented in a format not commonly used in ordinary language, with a separate line being employed for each proposition or premise. This format might lead reasoners to take each premise as a separate source of information and might therefore affect the way they draw conclusions. The aim of the present research is to examine whether certain reasoning effects could have been influenced by the practice of using such an atypical presentation format. Current reasoning theories acknowledge the particular relevance of superficial factors (Evans, 2003; Johnson-Laird,

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2006; Kahneman, 2011; Stanovich, 1999). However, there has been no study conducted to date exploring the effect that this traditional separation of the declarative sentences known as premises may have on the reasoning process. In this paper, we will present a direct comparison between this traditional presentation format (two-line presentation) and one-line presentation. In particular, we will investigate how the presentation format (two-line presentation versus one-line presentation) affects the reasoning process and the figural effect in syllogistic problems.

Syllogisms are arguments with two premises leading to a conclusion. For example:

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premise 1 : All of the A are B
premise 2 : All of the B are C
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conclusion: All of the A are C

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Both premises and conclusion are statements that use quantifiers of one of four types or moods:

- All A are B           (A)
- Some A are B       (I)
- No A are B           (E)
- Some A are not B   (O)

where the letters in parentheses are the traditional abbreviations for each kind of proposition. Each statement in the premises contains two terms: one (the middle term B), occurs in both premises, while the other two (A and C) are the end terms. The arrangement of the middle terms in each of the premises of a syllogism gives rise to a four-way classification, known as the figures of the syllogism:

Figure 1	Figure 2	Figure 3	Figure 4
B – A	A – B	B – A	A – B
C – B	C – B	B – C	B – C

Early studies showed that these figures generate different levels of difficulty (Dickstein, 1978; Fraser, 1968; Pezzoli & Fraser, 1968; Roberge, 1970). In some of these studies, it was found that syllogisms in figure 4 were more difficult to resolve than those in figure 1, while figures 2 and 3 had an intermediate difficulty (Dickstein, 1978). This author proposed that figure 4 was the most difficult, because people have to process the information backward, while in figure 1 syllogisms, they process the information forward. In figures 2 and 3, they can process both forward and backward. However, the reason why people had more difficulty with figure 4 than with figure 1 was that the conclusion was framed according to Scholastic logic: subject-predicate (with the subject being the end term of the second premise and the predicate the end term of the first premise). However, when participants were allowed to generate their own conclusions, it was found that in figure 4 syllogisms, there was a preference to build A-C conclusions, while in figure 1 syllogisms, there was a preference to build C-A conclusions (Johnson-Laird & Steedman, 1978, experiment 2). Also, it was found that when the syllogism had a valid conclusion in one direction but not the other (experiment 2), participants found the syllogisms in which the valid conclusion coincided with the figure (for example, an A-C conclusion in a figure 4 syllogism) easier to resolve than when the conclusion did not coincide with the figure (for example, a C-A conclusion in a figure 4 syllogism). These results have been replicated in a later study (Johnson-Laird & Bara, 1984). There, the authors found (experiment 3) that in figure 1 there was a preference to build conclusions in the order C-A (63%), while in figure 4 there was a preference to build conclusions in the order A-C (78%). These results led Johnson-Laird to introduce the Mental Model theory to explain the figural effect (Johnson-Laird, 1983). However, other authors offer different explanations for the figural effect (Chater & Oaksford 1999; Dickstein, 1978; Ford, 1995; Johnson-Laird & Bara, 1984; Oberauer & Wilhelm, 2000; Oberauer, Hörnig, Weidenfeld & Wilhelm, 2005; Polk & Newell, 1995; Stenning & Oberlander, 1995; Stenning & Yule, 1997; Wetherick & Gilhooly, 1990).

Wetherick & Gilhooly (1990) argue that the figural effect arises from the tendency to use a term that has appeared as the grammatical subject of one of the premises as the first term in the conclusion. In figure 4 (A-B/B-C), "A" is the subject of the first premise, so the preferred order of the end terms in the conclusion will be: A-C. In figure 1 (B-A/C-B), "C" is the subject of the second premise, so C-A will be more frequent.

Chater & Oaksford (1999) proposed a Probability Heuristic Model (PHM) to explain the figural effect. The most relevant heuristics in PHM to explain the “response bias” are the min-heuristic and the attachment-heuristic. The min-heuristic chooses the quantifier of the conclusion to be same as the quantifier in the least informative premise (the min-premise). The attachment-heuristic fixes conclusion order using the following procedure: if the min-premise has an end term as its subject, use this as the subject of the conclusion. Otherwise, use the end term of the max-premise as the subject of the conclusion. PHM predicts that the conclusion order is determined by the conclusion type. In other words, “the order of the end term is decided after conclusion type is selected” (Chater & Oaksford, 1999, p. 212).

Ford (1995) has proposed that some individuals (verbal reasoners) use set-theoretic principles, whereas others (spatial reasoners) use Euler circles when solving syllogisms. She found that in both groups, there was an effect of the figure in figure 1 and figure 4 syllogisms. Her conclusions for the spatial reasoner were that “more work needs to be carried out to reveal subtle factors affecting the order of terms in conclusions” (Ford, 1995, p.69). However, her predictions are more precise for the verbal reasoner. She argues that the participants manipulate the verbal form of the syllogism as an algebraic problem, by taking one premise as having a term that needs to be substituted with another term, and the other premise as providing a value for that substitution. The premise that provides the values for substitution acts as a rule relating membership of class ‘C’ to a property ‘P’, while the premise containing the term that needs to be substituted acts as a case of specific objects, ‘O’, whose status with regard to either ‘C’ or ‘P’ is known. She proposed four principles that are supposed to govern substitutions (Ford, 1995, page. 21). In relation to the figural effect, Ford claimed that the occurrence of a position effect or figural effect may be dependent on which part of the principle is being applied.

Oberauer & Wilhelm (2000) and Oberauer et. al. (2005) have proposed different factors to explain the figural effect during both the integration of premises and the inference stage. In the integration of the premises, they proposed two factors to explain the figural effect: the relatum (given principle) and the given-new principle. The relatum (given principle) arises from the directionality between relatum (or reference object) and target (target object) and the ensuing the order of construction of a mental model. In a sentence, the relatum is the reference object, while the term that is described relative to the relatum is the target object. For example, in the sentence “if p, then q”, “p” is the reference object or relatum and “q” is the term that is relative to it. Oberauer et al. (2005)

postulated that people prefer to build the mental model of the premises starting with the *relatum* term and add the target object to the *relatum*. In other words, there is an inherent directionality in every sentence that goes from the *relatum* object to the target object. The second factor is the given-new principle, according to which the assignment of an anaphoric expression to its antecedent is easier when the anaphor is mentioned before a new term. Also, Oberauer et al. (2000, 2005) have proposed two factors to explain the directional effect during the inference stage. The first factor is the inherent directionality of the relation between the target object and the *relatum*, which is preserved in the integrated mental model if, and only if, it is needed to preserve a semantic asymmetry. The other factor is a recency effect of working memory (Espino, Santamaría & García Madruga, 2000a). These authors have found that participants attempt to attach incoming information to the last element of the model. Recently, proponents of Mental Model theory have claimed that the definitive account of the figural effect 'is a semantic one due to Oberauer and his colleagues' (Khemlani & Johnson-Laird, 2012, page 431).

The anterior explanation of Mental Model theory (Johnson-Laird & Bara, 1984; Johnson-Laird & Byrne, 1991) of the figural effect was the 'FIFO principle'. In this paper, we adopt this hypothesis to explain our results. It provides an explanation of the figural effect based on two assumptions. First, the account proposes that in order to construct an integrated model of the two premises, reasoners attempt to bring middle terms (Bs) together. Second, it proposes that the way to state a conclusion is based on the principle "first in, first out" (henceforth, FIFO; Broadbent, 1958): the first piece of information entering the integrated model of the premises will be the first element in the conclusion. If the two middle terms of the premises occur in sequence (for example, the syllogism A-B/B-C), then the Mental Model theory proposes that the two premises can be easily combined to form an integrated model. In the syllogism A-B/B-C (figure 4), the first term in the integrated model is "A" and consequently, by the FIFO principle, the most frequent conclusion will be in the direction A-C. However, if the middle terms are not in sequence, additional operations will be necessary in order to bring together the middle terms. According to Johnson-Laird & Bara (1984), when the middle terms are not in sequence (as in figure 1: B-A/C-B), reasoners could use two different procedures to build the integrated mental model of the premises. First, the order of the terms within the first premise (B-A) and the second premise (C-B) could be switched round. For example, if the interpretation of "All A is B" is switched round, then it takes the form:

B [a]  
 B [a]  
 ...

Johnson-Laird (1983) affirms that “switching round an interpretation must not be confused with the operation of converting a premise, ..., the idea of switching round an interpretation concerns only the order of the information in working memory” (page 107). Switching round the terms in both premises in figure 1 brings the two middle terms together (A-B/B-C). Once the terms of the premises are in sequence, reasoners would select the conclusion, and the FIFO principle would determine the direction. As “A” is the first end term in the integrated model, it fills the first position in the conclusion.

The second strategy to build the integrated model consists in reversing (renewing) the order of the two models of the two premises. The way to proceed is to construct a model of the second premise (C-B) and then add the information from the first premise (B-A). Now the middle terms are in sequence (C-B/B-A) and the reasoner can build an integrated model. Once the terms of premises are in sequence, reasoners would select the conclusion, and the FIFO principle would determine the direction. As “C” is the first end term in the integrated model, it fills the first position in the conclusion.

It is not clear what mechanism might lead reasoners to choose one or the other strategy. However, this selection may well be influenced by superficial factors. Our prediction is that, in order to build the integrated model, participants will prefer to switch round the terms of premises (first strategy) for one-line presentation, and to reverse (or renew) the order of the premises (second strategy) for two-line presentation. Our prediction is founded in the idea that in one-line presentation, the placement of the premises prevents reasoners from treating them as separate units. In figure 4 (A-B/B-C), participants do not need to use any strategy to build the integrated model, because the middle terms are in sequence. However, for the remaining figures (figure 1, figure 2 and figure 3), if they want to build the integrated model, they have to use the first strategy in the first premise (figure 3), the second premise (figure 2) or both (figure 1). For example, in figure 1 (B-A/C-B) participants should use the first strategy in the first premise (converting B-A in A-B) and in the second premise (converting C-B in B-C). The consequence of using the first strategy, plus the FIFO strategy, in one-line presentation will be an increment of A-C conclusions in all figures as compared to two-line presentation. Also, we predict that in

one-line presentation, participants will produce more A-C than C-A conclusions in all figures.

When the format used is two-line presentation, we predict that participants will prefer to renew or reverse the order of premises (second strategy) as their first strategy and they will only switch round the terms of the premises (first strategy) as a secondary or complementary strategy. In figure 4 (A-B/B-C), participants do not need to use any strategy to build the integrated model, because the middle terms are in sequence. In this case, we predict that participants will produce more A-C than C-A conclusions. In figure 1 syllogisms (B-A/C-B), the easier way to build the integrated model is by using mainly the second strategy (C-B/B-A). In this case, we predict for figure 1 that reasoners will produce less A-C conclusions in two-line presentation than in one-line presentation.

In figure 2 and figure 3 (the symmetrical figures), there are two ways to obtain the integrated model. One procedure starts with the second strategy (the preferred one), after which the first strategy needs to be applied to obtain the integrated model. In that case, according to the FIFO principle, participants will produce more C-A than A-C conclusions. However, there is a second way to obtain the integrated model: using only the first strategy in figure 2 (in the second premise) and figure 3 (in the first premise). In this case, according to the FIFO principle, participants will produce more A-C than C-A conclusions. Because either procedure could be used to obtain the integrated model in the symmetric figures, we do not predict any differences for the direction of the answer (A-C versus C-A).

## **EXPERIMENT**

Our main objective in this experiment was to study the influence of the presentation format in a syllogistic reasoning task. Two formats were used: two-line presentation and one-line presentation (for example, All of the A are B. All of the B are C). In relation to the presentation format, we have postulated that when the premises are presented on a single line, participants will prefer to switch round the terms of the premises (first strategy) than to reverse (or renew) the order of the premises (second strategy), whereas when the premises are presented on two lines (separate premises), participants will prefer to reverse (or renew) the order of the premises (second strategy) than to switch round the terms of the premises (first strategy). As a result, we predict that the reasoners should present more A-C than C-A conclusions for the one-line presentation format. Also, we predict that in two-line presentation, reasoners should present more A-C

than C-A conclusions in figure 4 and more C-A than A-C conclusions in figure 1. No difference is predicted for figures 2 and 3.

## METHOD

**Participants and design.** A total of 78 students at the “Universidad de La Laguna” volunteered to participate. A mixed 2x4 design was used. The between-participant factor was the presentation format with two levels: one-line and two-line presentation. The second factor was the figure and had the four levels corresponding to the four figures. The dependent variable was the direction of responses (A-C or C-A).

**Materials and procedure.** Each participant received a total of eight experimental problems: two problems for each figure. The experimental syllogisms used were: AI1, EA1, EA2, AE2, IA3, AI3, IA4, AE4. All were one-model problems with valid conclusions in both directions (see Johnson-Laird and Byrne, 1991). In Table 1 we present an example of each type of presentation format and figure.

Participants were tested in a quiet room in groups of eight to ten. Their task was to consider a series of problems, and to draw a conclusion for each of the problems that had to be true, given that the premises were true. The problems were presented in random order to the individual participants in the form of booklets. Two types of booklets were used. In one, participants received the premises of the syllogisms in the one-line presentation format. In the second, participants received the second premise below the first premise in the traditional format (two-line presentation). There was no time limit set for performing the task.

The participants wrote down their own conclusions. These conclusions were labelled A-C when the first term in the conclusion was the end term in the first premise, and C-A when the first term in the conclusion was the end term in the second premise.

## RESULTS

Table 2 presents the percentages of valid and invalid conclusions in the A-C and C-A direction for each of the four figures and two presentation formats. Only those responses that included the middle term and one end term were eliminated (1%). We analysed the results for valid and invalid responses in an ANOVA carried out on the endorsements of inferences with the following factors: figure (figure 1, figure 2, figure 3 and figure 4), direction of response (A-C versus C-A) and presentation format (one-line



presentation versus two-line presentation), with repeated measures on the first two factors and the last acting as a between-participant variable. The Greenhouse-Geisser correction for the violation of sphericity assumption was used in this analysis. This analysis revealed an interaction between direction of response and figure ( $F(3,228) = 5.51$ ,  $Mse = .14$ ,  $p < .001$ ,  $\eta_p^2 = .07$ ) but not between figure and presentation format ( $F(2.157, 163.917) = .52$ ,  $Mse = .00$ ,  $p = .67$ ,  $\eta_p^2 = .01$ ). There was no main effect for the figure ( $F(2.157, 163.917) = 1.28$ ,  $Mse = .00$ ,  $p = .28$ ,  $\eta_p^2 = .02$ ). There were main effects for direction of response ( $F(1, 76) = 29.05$ ,  $Mse = .31$ ,  $p < .001$ ,  $\eta_p^2 = .28$ ) and the interaction was reliable between direction of response and presentation format ( $F(1, 76) = 10.55$ ,  $Mse = .31$ ,  $p < .002$ ,  $\eta_p^2 = .12$ ). There were no effects for the triple interaction between figure, presentation format and direction of response ( $F(3, 228) = 1.54$ ,  $Mse = .14$ ,  $p = .20$ ,  $\eta_p^2 = .12$ ). There were no effects for the between-participant variable ( $F(1, 76) = .15$ ,  $Mse = .00$ ,  $p = .70$ ,  $\eta_p^2 = .00$ ).

A subsequent analysis showed that in one-line presentation, participants gave more A-C than C-A conclusions in figure 4 (76% versus 23%;  $z = 3.94$ ,  $p < .001$ ), figure 1 (66% versus 34%;  $z = 3.03$ ,  $p < .003$ ) figure 2 (67% versus 33%;  $z = 2.83$ ,  $p < .006$ ) and figure 3 (68% versus 31%;  $z = 3.32$ ,  $p < .002$ ). A further analysis showed that in two-line presentation, participants gave more A-C than C-A conclusions in figure 4 (66% versus 34%;  $z = 2.68$ ,  $p < .006$ ) but they gave more C-A than A-C conclusions in figure 1 (58% versus 40%;  $z = 1.93$ ,  $p = .053$ ), although the differences were not reliable. No reliable differences were found between the percentage of A-C and C-A responses in figure 2 (59% versus 41%;  $z = 1.60$ ,  $p = .10$ ) and figure 3 (53% versus 45%;  $z = .99$ ,  $p = .32$ ).

## DISCUSSION

In this paper, we have reported a consistent result that is new in the psychology of reasoning. The classical figural effect can be reversed (figure 1 in one-line presentation) by simply arranging the premises in a different way: participants generate more A-C than C-A conclusions in figure 1 syllogisms when a one-line presentation is used. Also, a new effect could be obtained for figure 2 and figure 3 in the sense that participants produce more A-C than C-A conclusions with this presentation format. It is worth mentioning that in previous studies in which two-line presentation was used, no directionality effect was found for figures 2 and 3 (Johnson-Laird & Bara, 1984).

**Table 1. Examples of materials from Experiment 1.**

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**Presentation in one line****Figure 1****All of the British are Artists. Some of the Teachers are British.****Figure 2****All of the Artists are British. None of Teachers are British.****Figure 3****All of the British are Artists. Some of the British are Teachers.****Figure 4****Some of the Artists are British. All of the British are Teachers.****Presentation in two lines****Figure 1****All of the British are Artists.  
Some of the Teachers are British.****Figure 2****All of the Artists are British.  
None of the Teachers are British.****Figure 3****All of the British are Artists.  
Some of the British are Teachers.****Figure 4****Some of the Artists are British.  
All of the British are Teachers.**

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**Table 2. Percentages of valid and invalid responses A-C and C-A according to the presentation format (one-line presentation and two-line presentation) and figure type (figure 1, figure 2, figure 3, figure 4). In parentheses, the percentages of correct responses.**

	one-line presentation		two-line presentation	
	A-C	C-A	A-C	C-A
Figure 1	66	34 (91)	40	58 (89)
Figure 2	67	33 (87)	59	41 (96)
Figure 3	68	31 (87)	53	45 (84)
Figure 4	76	23 (82)	66	34 (89)
Total	69	30 (87)	55	45 (90)

On the other hand, with the traditional presentation format (two-line presentation) we have obtained results that confirm the figural bias: in figure 1 syllogisms, participants gave more C-A than A-C conclusions, while in figure 4 syllogisms, participants gave more A-C than C-A conclusions. Consequently, this result confirms the usual findings in this field (Johnson-Laird & Bara, 1984; Ford, 1995; Polk & Newell, 1995). For example, Johnson-Laird & Bara (1984; Experiment 1, 60-sec. presentation condition), using the two-line format presentation, found that the accuracy of the performance for the same problems that we used in this experiments was 93%, while in our study it was 90% (Table 2).

To explain this new pattern, we have suggested that in a one-line presentation, participants are more prompted to use the 'switching strategy', because they see the premises as one unit. However, in two-line presentation, the two premises could be seen as separate units. In this case, we suggest that participants can use the two strategies: the 'renew strategy' and the 'switching strategy'. They apply the 'renew strategy' when they see the premises as separate units and they apply the switching strategy when the 'renew strategy' cannot be used.

This explanation is consistent with the FIFO explanation, because this point of view claims that reasoners can use two different strategies to rearrange the elements in syllogisms and produce conclusions. This explanation points out that the position of the end terms in the conclusion is determined by their position in the integrated model. For example, if the participants reverse the order of the premises in figure 1 syllogisms, then 'C' will be the first term in the integrated model and it will appear as the first term in the conclusion. Conversely, if they switch round the individual premises, 'A' will be the first term in the integrated model and it will initiate the conclusion. According to the FIFO explanation, it could be maintained that with one-line presentation, the participants gave priority to the switching round strategy within premises over a strategy that went between premises. It is reasonable to assume that the latter strategy is more difficult to envisage and perform when the superficial cues of premise position are not given.

Other theories (Chater & Oaksford, 1999; Ford, 1995; Oberauer & Wilhelm, 2000; Oberauer et. al, 2005; Polk & Newell, 1995; Wetherick & Gilhooly, 1990) cannot explain the order of the end terms in the conclusion when the syllogism is presented in one-line presentation. For the syntactic hypotheses (Wetherick & Gilhooly, 1990; Polk & Newell, 1995), the order of the terms in the conclusion is determined by the syntactic role that each term plays in the premises: if the end term is the subject of the premise, then reasoners use that term as the subject of the conclusion. As our variations of the presentation format did not affect the syntactic role of each end term, syntactic theories cannot explain our results, and this implies that the figural effect usually found in figure 1 (reproduced in our two-line presentation) remains unexplained from this point of view. The syntactic factors cannot be affected by the superficial placement of the premises.

The Probabilistic-Heuristic Model (Chater & Oaksford, 1999) suggests that conclusion order is determined by the attachment-heuristic. The prediction of this model for figure 1 syllogisms is that participants will tend to draw conclusions in the direction "C-A". Although this prediction could explain the results obtained in traditional two-line presentation, it does not fit our one-line presentation results where participants constructed conclusions in the "A-C" direction.

Ford (1995) proposed an explanation of the figural effect in terms of set-theoretical principles. Once again, our manipulation of the presentation format should not affect the set-theoretical principles that could be applied, so this theory is unable to explain our results.

Finally, Oberauer & Wilhelm (2000) and Oberauer et al. (2005) have proposed an explanation of the figural effect during the inference stage based on two factors: a)

the inherent directionality of the relation between the target object and the relatum and b) the recency effect of working memory. However, our manipulation of the presentation format should affect (or not affect) both factors in the same way, so this theory is unable to explain the results we obtained when the one-line presentation is used.

In summary, the results reported in this paper, taken together with other recent results achieved using different methodologies, such as measuring the activation of the end terms (Espino, Santamaría & García-Madruga, 2000a), reading time of premises (Espino, Santamaría & García-Madruga, 2000b) or eye-movement monitoring (Espino, Santamaría, Meseguer & Carreiras, 2005), give a clear primacy to the FIFO explanation to account for the figural effect.

## RESUMEN

**Formato de presentación y razonamiento silogístico.** El efecto de la figura es un sesgo de respuesta que depende de la disposición de los términos en los silogismos. El resultado más usual, en una tarea de construcción, es que los participantes tienden a dar la respuesta en la dirección A-C cuando los silogismos son de la figura 4 (A-B/B-C), mientras que la mayoría de sus conclusiones son en la dirección opuesta (C-A) en la figura 1 (B-A/C-B). Presentamos un experimento que estudia el papel del tipo de formato de las premisas (presentación en dos líneas versus presentación en una línea) en silogismos categóricos. Los resultados obtenidos muestran que cuando la presentación de las premisas fue en el formato de una línea, los participantes generaban más respuestas A-C que respuestas C-A en todas las figuras silogísticas. Sin embargo, cuando la presentación de las premisas fue en dos líneas, los participantes generaban más respuestas A-C en los silogismos de la figura 4 y más respuestas C-A en los silogismos de la figura 1, pero no se encontraron diferencias significativas ni en los silogismos de la figura 2 (A-B/C-B) ni en los de la figura 3 (B-A/B-C). En este artículo discutimos las implicaciones de los resultados para las distintas teorías de razonamiento.

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