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# Sex Differences in Object Location Memory

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The ability to remember where objects were is thought to require multiple separate processes. One has to encode the precise positions occupied, assign the various objects to the correct (relative) locations, and achieve an integration of both types of spatial information. This study examined whether sex differences exist for these selective components of object location memory. Twenty males and 20 females participated in the following task. On a PC screen, they were shown a square with 10 different objects for 30 s. Subsequently, the objects disappeared from the screen, reappeared in a row above the square, and subjects were asked to relocate them in three different conditions. In the object-to-position-assignment condition, the original positions were premarked in the square, so subjects needed only to assign the correct object to the correct position. In the positions-only condition, all objects assumed the same identity. Therefore, subjects had only to reproduce the precise positions. Finally, in the combined condition, subjects were required to replace all the different objects in the square without any of object positions premarked. The absolute displacements between an object's original and its relocated position reflect the integration mechanism. Females did as well as males in the object-to-position-assignment condition and on the absolute displacements in the combined condition, but they were less efficient than males in positional reconstruction per se. Thus, it seems that the male advantage in spatial memory is not a general effect but applies only to certain specific processing components. Moreover, the employment of a dual task during encoding, concurrent articulatory suppression, yielded no significant interactions with sex. This suggests that females' weaker positional encoding does not derive from the use of an inefficient verbal strategy.

## INTRODUCTION

Differences between men and women in spatial abilities are well documented. In general, males tend to be better on spatial tasks like mental paper folding, maze learning, map reading, and aiming at and tracking objects. Among the factors held to be responsible for these differences, variations in cerebral maturation rate and hormonal, genetic, and cortical lateralization,

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as well as sociocultural influences have been listed (see Harris, 1981; Kolb & Whishaw, 1995; Maccoby & Jacklin, 1974, for overviews). However, it has also been noted that spatial ability is a rather broad concept, encompassing a wide diversity of activities. Linn and Petersen (1985) point out that there exists considerable dispute on which aspects of spatial abilities show a male advantage and to what extent. Even though males are superior on most spatial tasks on others the difference is absent, and on a few it is even reversed (e.g., Eals & Silverman, 1994; Silverman & Eals, 1992; Uecker & Obrzut, 1993; Voyer & Bryden, 1990). Task complexity, stimulus familiarity, and the nature of the precise processes tested could be important in this respect. In a meta-analysis over multiple studies, Linn and Petersen (1985) identified three major spatial categories: spatial perception, mental rotation, and spatial visualization. They argued that clear sex differences were restricted to tests of the second category.

In line with the foregoing remarks, the purpose of the present study was to investigate the possibility of sex differences in spatial memory. We used a task which was designed to evaluate the different processing components that are involved in memory for object locations. Basically, object location memory requires subjects to reconstruct the positions of various previously studied objects. Typically, presentation and reconstruction of object locations takes place in a restricted area, like within a frame on a computer screen or on a table top (cf. Postma & De Haan, 1996; Smith & Milner, 1981, 1984). In a recent study (Postma & De Haan, 1996), we argued that at least two processes can be distinguished. First, one needs to remember the precise positions where objects were placed. Second, one has to remember which object was at what (relative) position. In addition, a third, separate processing stage might be identified which entails the integration of both types of information.

A number of findings support the foregoing distinction. It was observed that the number of objects to be remembered, and the presence or absence of articulatory suppression had substantial effects on the efficiency of *object to position assignment* but had little effect on *positional encoding* (Postma & De Haan, 1996; Igel & Harvey, 1991). Contrary, positional encoding deteriorated when the size of relocation space increased, whereas this was not the case for object to position assignment (Postma & De Haan, 1995). Moreover, Shoquierat and Mayes (1991) reported that the spatial memory abilities of amnesics were particularly poor on object-to-position assignment. Finally, Schuman-Hengsteler (1992) observed that older children performed better than younger ones in remembering the locations of specific objects but not in remembering the positions themselves.

In the present study, we compared male and female subjects on a spatial memory task in which they had to replace 10 objects in three different conditions. In the object-to-position-assignment condition, subjects only needed to assign the objects to the correct, premarked position. In the positions-only condition, all objects were the same, so they had to reproduce only the original positions. In the combined condition, subjects were required to replace all the different objects in the square. This condition thus comprises both positional encoding and object-to-position assignment, and tested their integration.

Even though a number of studies report sex differences on spatial memory tasks (e.g., Miller & Santoni, 1986; Orsini, Chiacchio, Cinque, Cocchiaro, Schiappa, & Grossi, 1986; Sharps, Welton, & Price, 1993), typically indicating male superiority, it remains unclear to which of the previously described object location memory processes this applies. Kail and Siegel (1977) found a male advantage for recall of 5 or 7 positions in a 4 × 4 matrix. In contrast, when it was analyzed whether the correct item was in the correct position—like in our combined condition—this advantage seems to disappear.[1] However, it should be noted that sex differences were a bit variable over the three age groups tested by Kail and Siegel. More importantly, the spatial nature of their task may be questioned, since the 4 × 4 matrix allowed ample opportunity for verbal coding of location information (cf., Postma, 1996).

Miller and Santoni (1986) studied the reliance on topological versus Euclidian cues in giving directions from memory between various locations on the map. Males used more Euclidian cues and were more accurate, whereas females were more tuned to landmarks. This could suggest males to be superior in particular on the aspect of positional encoding per se.

Related to this possibility is a recent proposal on the perception of space advanced by Kosslyn (1987). Kosslyn argues that we perceive two types of spatial relations. Coordinate representations preserve fine-grain locational information within a metric coordinate system. Categorical spatial encoding, on the other hand, is a more coarse, abstract way to determine relative spatial relations between objects or parts of an object, such as left/right and above/below. Categorical relations supposedly are nonmetric, propositional. Moreover, it is argued that the right hemisphere is specialized for processing coordinate information, whereas the left hemisphere holds an advantage for categorical relations. Rybash and Hoyer (1992) have hypothesized that women would be superior for categorical tasks and men for coordinate tasks because the former depend on representations with a strong language component, whereas the latter are language free, more truly spatial. Their data from a spatial perception paradigm support this claim. Elsewhere (Postma & De Haan, 1996), we have suggested that in object location memory positional encoding per se may mainly call upon coordinate information, enabling one to retain absolute positions and Euclidian distances between objects. In addition, object-to-position assignment might rely strongly upon categorical information of the type: object A is to the left of and above object B. Hence,

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[1] Unfortunately, Kail and Siegel (1977) did not report any statistical tests of the sex difference for this relocation measure.

one could expect a male advantage for positional reconstruction per se, while females might do better in object-to-position assignment.

Studies by Silverman and Eals (Silverman & Eals, 1992; Eals & Silverman, 1994) have yielded some surprising results in showing females to surpass males in spatial memory. The tasks employed by these authors included a test in which it should be marked which of 20 items on a previously studied stimulus card had changed places, and a test in which subjects were asked to describe from memory the locations of common and uncommon objects in an office room. Both cases can be considered to require mostly a (categorical) relative judgment of position, and thus would tap primarily the object-to-position-assignment mechanism.

In light of the foregoing, the present study allowed a more extended, systematic test of whether sex differences prevail at all in object location memory, involve only a selective aspect (i.e. either positional encoding or object to position assignment), or occur when integration of both aspects is called for (as in the combined condition). As a further manipulation, we engaged the use of an articulatory suppression condition. On half the trials, subjects studied the stimuli in a single-task condition, whereas on the other half they had to repeat the nonsense-syllable *blah* during stimulus presentation. Several studies have revealed that articulatory suppression prevents verbal processing of information in working memory but does not affect concurrent visuospatial processes (cf. Logie, Zucco, & Baddeley, 1990; Morris, 1987). The difficulty of the interference task needs to be carefully calibrated. If the task is too easy, it will still allow verbal rehearsal of materials. If the task is too difficult, it consumes too many general resources and thus hampers also nonverbal processes. Our selection of *blah* rehearsal during encoding was motivated by earlier findings that it can selectively affect object to position assignment but not positional encoding (Postma & De Haan, 1996, experiment 3). Hence it seems to yield a restricted, presumably verbal, interference effect. It has been suggested that a possible contributing factor to sex differences could be the greater reliance on verbal mediation of females. For spatial tasks, this strategy would clearly be a less efficient mode of information processing (Harris, 1981). A similar explanation has been suggested by Kearins (1981) with respect to the superior spatial memory performance of aboriginal children compared to white Australian youths. If any differences obtained in our object location memory task derived from females choosing an inadequate verbal strategy, we would expect them to suffer especially by the verbal interference task.[2]

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[2] Of course, one can also make the case for a completely reverse effect of verbal interference here. By preventing verbal processing, it makes females return to the appropriate visuospatial strategy. Consequently, they may become as good as men, or—there still being an essential difference—somewhat inferior but to a lessened extent. What is important is that both possibilities predict an interaction between sex and task condition.

# METHOD

## *Subjects*

Twenty females (age between 18 and 37 years; mean = 23.7, *SD* = 4.7) and 20 males (age between 19 and 33 years; mean = 23.7, *SD* = 3.2) participated in the experiment. They were all students from the Utrecht University, and they were paid for their participation. None of them reported any memory or concentration problem, and they all had normal or corrected-to-normal eye vision. A Dutch translation of the revised Annett Handedness Inventory (Briggs & Nebes, 1975) was administered, and men scored a mean of +19.8 (*SD* = 4.2), and women scored a mean of +20.6 (*SD* = 3.9). This difference did not approach significance on a student *T*-test.

In order to control for possible group differences in object identification, two short control tasks were carried out. First, the objects used in the main experiment were presented individually, and subjects had to name each item as fast as possible. Vocal latencies were registered with a voice key, and errors were recorded. In the second control task, all objects were presented in pairs for a same/different decision. In total, 76 pairs were presented, and errors and response latencies were recorded. Both control tasks yielded no significant sex effects. Hence, we conclude that the two groups were equally proficient in the visual processing of the objects used in our object location memory stimuli.

## *Materials*

A stimulus consisted of black square frame (15 × 15 cm) on a gray background projected on a computer screen. The square always contained 10 objects: black line drawings of highly familiar items. On average, objects were about 1 × 1 cm. For each stimulus, a random selection of 10 was chosen from the following set of 19 objects: banana, bell, book, letter, paper clip, cupboard, Christmas tree, clock, light bulb, umbrella, telephone, airplane, pencil, key, padlock, trash can, water tap, bicycle, magnet. The objects shown in a stimulus were always evenly distributed across the square.

## *Procedure*

In an experimental trial, a stimulus—a square frame containing 10 objects—was shown for 30 seconds on the screen. Subsequently, the objects disappeared, reappearing in a random order on a row above the square. Subjects were seated approximately 40 cm from the screen and were asked to replace the objects with the computer mouse. Three relocation conditions were tested. In the object-to-position-assignment condition, the positions previously occupied were premarked by a dot. Therefore, subjects had only to remember which object was at what position. In the positions-only condition, all objects that appeared in the square were the same. Thus, subjects had only to remember the precise positions. Finally, in the combined condition, all different objects were displayed and had to be relocated without the help of premarked positional marks. This condition entails both object to position assignment and positional encoding. Subjects were instructed to relocate all items as accurately as possible. There were no time limits, and they were free to change each position as often as they wished. Half of the trials were performed in a single-task condition, whereas in the other half subjects were required to repeat the nonsense-syllable *blah* aloud during the study phase. When subjects paused too long, they were prompted by the experimenter. The three relocation conditions were presented in blocks. Each block contained 6 trials, the first 3 were done with articulatory suppression, and the latter three without, or the order was just reversed. Each first and fourth trial (i.e., when switching from articulatory suppression to silent, or the other way around) in a block were practice trials. At their beginning, the experimenter told the subjects which relocation condition was going to be tested and whether the following trials should be done with articulatory suppression or not. In total, the experiment consisted of 6 practice and 12 experimental trials. All trials included different objects sets and different spatial layouts. Order of relocation conditions, as well as those of task conditions within a relocation condition, was varied over subjects in a group but was the same for the two groups as a whole.

### *Data Analysis*

The error score computed in the object-to-position-assignment condition was the percentage mislocated objects. For the positions-only and the combined condition, this procedure poses problems because the objects will almost never be relocated in exactly the same original location. We, therefore, chose to use the distance between the original and reconstructed location as the error measure. A further problem with the position-only condition is that one can never be sure about which original and which relocation belong to each other. Hence, we computed a *best-fit* measure based on the pairing of original to relocated positions which yielded the smallest error for the stimulus as a whole. What one has to do is to compute these errors for all the orderings possible and to select the one which is smallest. The number of possible orderings is equal to the faculty of the number of locations displayed (i.e., 10! in the present study). For the combined condition, a similar best-fit score was derived by ignoring object identities. This best-fit measure reflects the degree in which a subject has placed an object, whether it is the correct one or not, close to a correct position. Finally, the combined condition allows for a further error measure in which the object identities are taken into account. We defined the *absolute error* as the displacement between an object's original and its relocated position. It can been argued to reflect the integration of positional encoding and object to position assignment accuracy. For a further discussion of these error measures see Postma and De Haan (1996).

## RESULTS

### *'Object-to-Position-Assignment' Condition*

Figure 1 shows the percentage mislocated objects as a function of sex (males versus females) and task condition (with and without articulatory suppression). A two-way analysis of variance yielded only one significant main effect [$F(1, 38) = 12.26$, $p < .01$] for task condition: relocation was better without articulatory suppression. The interaction was not significant.

### *Positions-Only and Combined Condition*

Figure 2 shows the positional reconstruction per se (best-fit scores) for the positions-only and the combined condition for males and females, with and without articulatory suppression. There was a significant main effect for group [$F(1, 38) = 7.39$, $p < .01$]. Males were better at positional reconstruction than females. The factors task condition [$F(1, 38) = 15.74$, $p < .01$] and relocation condition (positions-only versus combined) [$F(1, 38) = 25.76$, $p < .01$] also yielded significant main effects. Relocation performance was superior without articulatory suppression and in the positions-only compared to the combined condition. The only significant interaction obtained was between the factors relocation condition and task condition [$F(1, 38)$

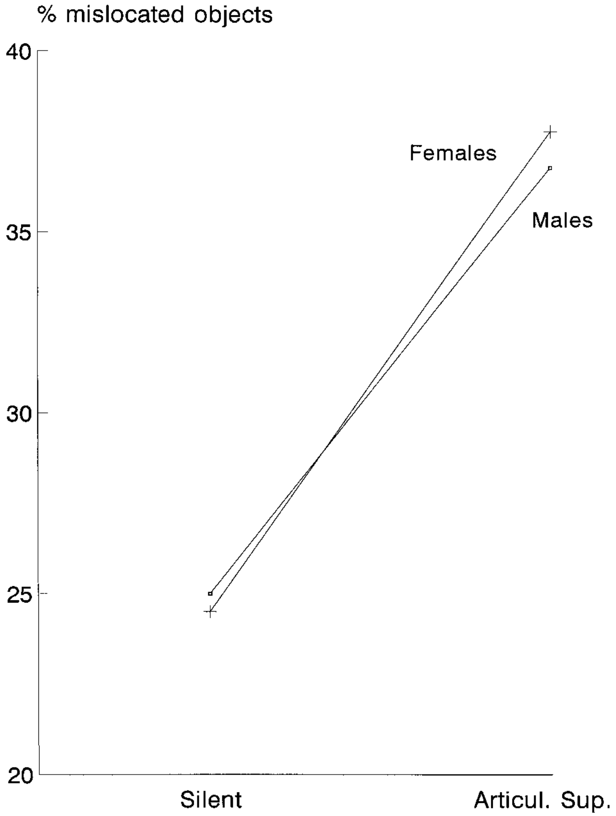

**FIG. 1.** Percentages mislocated objects as a function of sex (males versus females) and task condition (silent and with articulatory suppression) in the object-to-position-assignment condition.

$= 4.30$, $p < .05$]. In the positions-only condition articulatory suppression effects were somewhat larger than in the combined condition.

Figure 3 presents the absolute errors for the combined condition. The analysis of variance showed a significant task condition effect [$F(1, 38) = 14.26$, $p < .01$], indicating that with articulatory suppression performance dropped. There was no difference between men and women, nor a sex by task condition interaction.

## DISCUSSION

Object location memory rests upon three processing components: the encoding of the precise positions occupied, the assignment of objects to positions, and their integration. It was the purpose of the present study to investi-

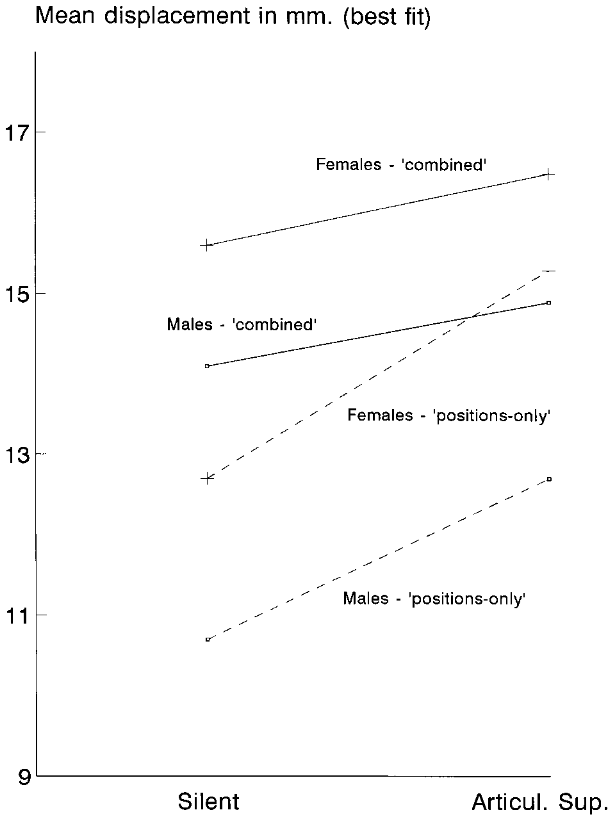

**FIG. 2.** Mean displacement (best fit) in millimeters as a function of sex (males versus females), task condition (silent and with articulatory suppression), and relocation condition (positions-only versus the combined condition).

gate the possibility of a sex difference for object relocation memory and, if so, for which of these processes this difference would hold.

In the object-to-position-assignment condition, no sex effect was found. Females and males seem equally skilled in linking objects to positions. There was a significant effect of articulatory suppression. This observation is in line with our earlier findings (Postma & De Hann, 1996) and indicates a potential relation of object-to-position assignment to verbal processing. No sex by task condition (with or without articulatory suppression) interaction was obtained. In the other two relocation conditions, a clear difference between the sexes was observed. Interestingly, positional reconstruction per se was significantly better for males than females in both the positions-only and the combined condition. Furthermore, task condition and relocation condition (positions-only versus the combined condition) yielded significant

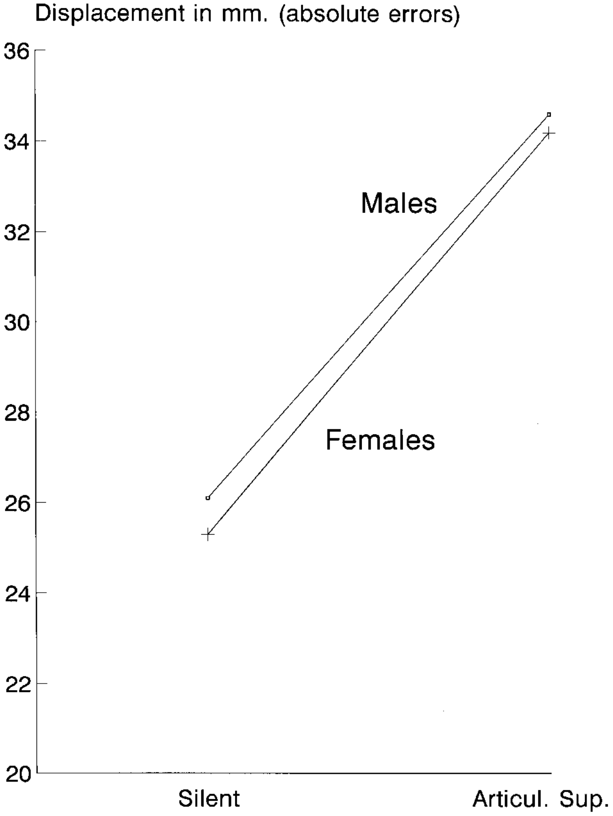

**FIG. 3.** Mean displacement (absolute error) in millimeters as a function of sex (males versus females) and task condition (silent and with articulatory suppression) in the combined condition.

main effects.[3] No sex by task condition interaction was present. Taken together, these data suggest that positional encoding per se is weaker in females and that this is not caused by choice of a less efficient—verbal—processing strategy.

The latter conclusion—that sex differences in spatial memory are not ac-

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[3] This does not accord with certain findings in Postma and De Haan (1996). In Experiment 3 of that study, we observed that positional reconstruction per se (best fit) was insensitive to verbal interference and did not differ for the two relocation conditions. In the present study, however, these effects were present. Several changes exist between the two studies which might be responsible for this. Most of all, we want to point out that we used a larger square here. Elsewhere, we have demonstrated that increasing the size of relocation space by using a larger square—as in the present study—causes a change in positional reconstruction. For example, it becomes affected by object number and relocation condition (Postma & De Haan, 1995).

counted for in terms of the employment of verbal processing strategies—is limited, though, by the fact that all spatial measures analyzed were affected by the secondary task. Thus, it is possible that the secondary task does not particularly obstruct ongoing verbal processing, but exerts its influence by means of some form of general capacity reduction. Other studies, however, have indicated that, besides such a general effect, articulatory suppression competes specifically with verbal processing of information in working memory (see Logie et al., 1990; Morris, 1987; also note 3).

For the combined condition, a second error measure was computed: the absolute errors, reflecting the integration of information about object-to-position relations with precise metric positional information. Absolute errors thus can be seen as a composite of both positional encoding accuracy and object-to-position-assignment accuracy. Men and women performed identically on this measure, indicating equal efficiency of the integration mechanism. Given that positional encoding accuracy was worse in females, it is remarkable that no sign of this effect was found in the absolute errors. The most likely explanation is that this particular relocation measure is much more influenced by object-to-position-assignment accuracy than by positional encoding accuracy. If a subject reverses the position of two objects, the resulting error measured in millimeters is much larger than the expected range of error caused by simply displacing a previously occupied position.

The absence of a sex effect in some conditions of this task is helpful in ruling out an alternative account of the present results. Sharps et al. (1993) argued that a priori beliefs and expectations may cause women to do worse on a number of spatial tasks. They demonstrated that when task characteristics and instructions disguised the spatial nature of a task, differences between males and females were reduced. In our experiment, the nature of the task was made explicit at the outset. If females do worse simply out of foreknowledge that they are going to be tested upon a *spatial* task, it is strange that they did so here only for positional reconstruction per se and not in the object-to-position-assignment condition and for the absolute errors of the combined condition.

On first sight, our data appear to conflict with studies by Silverman and Eals (1992; Eals & Silverman, 1994) which demonstrated a female advantage in spatial memory. Their experiments primarily assessed the retention of relative locations of objects. The presently obtained male superiority applies to memory for precise, Euclidian spatial information, not tested by these authors. The question then seems to be Why did we not find females to do better in object-to-position assignment. One possibility is that while Silverman and Eals had a short 1- to 2-minute delay inserted between study and test, we asked for immediate recall of locations. Future research might thus compare males and females on immediate and delayed spatial memory tests. Another reason could be the number of objects/locations presented. Silverman and Eals worked with 20–25 different objects, about twice the number we used. Maybe when the object-to-position-assignment tasks get more complex, sex differences favoring females will appear.

In short, the present results indicate that males may be better than females in the encoding of precise positional information but not in the assignment of object to positions nor in their integration. As mentioned in the introduction, positional encoding per se might specifically rely upon the processing of what Kosslyn (1987) has coined coordinate spatial relations. In turn, object-to-position assignment seems to depend upon categorical spatial relations. Rybash and Hoyer (1992) have observed that males are superior in coordinate tasks and females, in categorical tasks. As such, it is of considerable interest that positional encoding per se—supposedly a coordinate task—showed a male advantage whereas object-to-position assignment—the more categorical task—did not. This partly seems to corroborate our attempts to integrate the distinction between positional encoding per se and object-to-position assignment within Kosslyn's model.

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