Research Article

Induced Perceptual Grouping

Timothy J. Vickery

Harvard University

ABSTRACT—*The term* perceptual grouping *is associated with classical principles such as similarity and proximity. This article reports* induced *perceptual grouping, a phenomenon that occurs when placement of a uniform set of items near a structured set induces grouping within the otherwise uniform set. For example, when items grouped pair-wise by similarity are placed near another set of unstructured items, an analogous pair-wise grouping links elements of the second set. Induced grouping affected reaction times in two different visual search tasks, with reaction times depending on whether the target properties were contained within a group or crossed group boundaries as defined by induced grouping due to similarity, proximity, or common fate. Induced grouping was reduced when grouping between the structured and unstructured sets was weakened by means of a common-region cue or decreased similarity. Induced grouping appears to reflect the computation of hierarchical structure in visual images.*

Inferring structure in visual scenes is critical to understanding the environment. Although the structure of the world is reflected in the structure of the image (Gibson, 1979), it is obscured by problems such as occlusion and lighting variation. Nevertheless, the human visual system seems to process structure effortlessly. The study of perceptual organization has identified many principles by which the visual scene is parsed into elementary units, which are divided into figure and ground and recombined to form surfaces, objects, and groups (Palmer & Rock, 1994). Classical research has shown that, all else being equal, scene elements that are similar to one another, are close to one another, and move in concert are "grouped" together (Wertheimer, 1923/1950), warping spatial perception (Coren & Girgus, 1980) and affecting the distribution of attention (Dodd & Pratt, 2005). Yet these principles, and recent additions such as the principles of element connectedness (Palmer & Rock, 1994) and common region (Palmer, 1992), are inadequate to solve the problem of perceptual organization by themselves (Buhmann, Malik, & Perona, 1999; Roelfsema, 2006).

This article reports a novel observation that provides clues about how the limitations of these grouping principles may be overcome, in part. Consider a row of circles that are evenly spaced and have identical features. Although applying the principles of grouping to this set may suggest that these circles "belong" together, the row is unstructured in the sense that no two adjacent circles are paired preferentially compared with any other two adjacent circles. Now, introduce a parallel set of elements with structure from grouping (e.g., the elements are grouping by similarity). If traditional means of grouping are applied to this combination, the unstructured row remains unstructured: Any given pair shares no more properties after the addition of the new items than before.

Figure 1a shows several examples in which a row of unstructured items is grouped with a row that is strongly structured by similarity, proximity, or connectedness. In each case, the undifferentiated items are subjectively grouped pair-wise because they are grouped with a strongly structured set. These demonstrations imply that grouping has an indirect influence on the perception of structure, which "spreads" from structured sets to otherwise unstructured sets. This effect may be referred to as *induced* perceptual grouping, because one set of items induces perception of structure in another set of items.[1] These examples suggest a generalizable extension of basic principles: In the absence of other factors, if an unstructured set is grouped with a structured set, an analogous grouping is induced in the otherwise unstructured set. This induction process satisfies *ceteris paribus* requirements—it determines grouping when other grouping factors are held equal, a defining quality of grouping principles (Palmer, 1992).

How is induced grouping produced? Computational theories have explored relevant possibilities for extending grouping principles. One recurring theme is that of hierarchical structure, sometimes formalized as a treelike structure (e.g., Feldman, 1997; Shi & Malik, 2000) or with transitive rules (if element A groups with B, and B with C, then A groups with C; Geisler & Super, 2000; Roelfsema, 2006). Figure 1b (inspired by Geisler & Super, 2000) shows that similarity can transitively connect

Address correspondence to Timothy J. Vickery, Vision Sciences Lab, Department of Psychology, Harvard University, 33 Kirkland St., 7th Floor, Cambridge, MA 02138, e-mail: tim.vickery@gmail.com.

[1] I thank Stephen Palmer for suggesting this term.

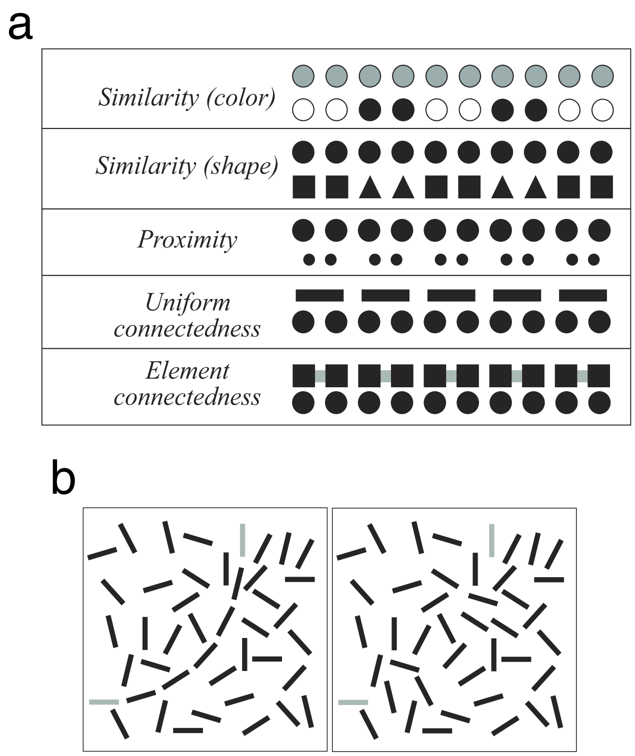

Fig. 1. Examples of (a) induced grouping in the organization of equally spaced circles and (b) transitivity in contour grouping (inspired by Fig. 4 of Geisler & Super, 2000). Note that in each example in (a), the row of undifferentiated items is subjectively grouped according to the organization of the differentiated row next to it. In (b), note that the distant, highlighted bars in the left-hand image are grouped with one another because of transitivity of similarity grouping in intervening items, but that these bars are not grouped when the intervening items are randomly oriented, as in the right-hand image.

distant contour elements: The highlighted elements are grouped in the example on the left, but not in the example on the right. Transitivity may also explain the induced grouping in Figure 1a. Each element in an unstructured row is grouped equally by proximity with its neighbor (or neighbors) and with the element directly above or below; the latter element is grouped preferentially with one of its horizontal neighbors, which in turn is grouped with one of the original object's neighbors, forming a superordinate U-shaped group. These chains link pairs on the undifferentiated row, inducing a structured percept where traditionally applied grouping principles suggest no structure. The novel examples in Figure 1a are an affirmative answer to the question of whether elements linked solely by hierarchical structure can really be considered to be grouped.

It is also possible that induced grouping is due to the spread of attention, a notion previously raised as an explanation for other forms of grouping (e.g., Driver, Davis, Russell, Turatto, & Freeman, 2001; Scholl, 2001). According to this account, attention is drawn by the grouped pairs of the structured row and spreads to proximal elements on the unstructured row, leading to the perception of grouping. Accounts based on transitivity and those based on attention are not necessarily mutually exclusive.

Although induced grouping is less potent than direct grouping by principles such as similarity, informal polling of observers confirms that the unstructured rows in Figure 1a are consistently grouped into pairs by induction. However, the effect is subject to interpretation: Does induced grouping occur unintentionally, and thus affect performance incidentally, or does it occur intentionally because of unavoidable demand characteristics when a subjective report is elicited? This article reports three experiments that empirically validate induced grouping by demonstrating that it occurs unintentionally. Experiments 1 and 2 employed the repetition-discrimination task (Beck & Palmer, 2002; Palmer & Beck, 2007) to evaluate the potency and intentionality of induced grouping. Experiment 3 confirmed the results with a novel paradigm, and shows that interset grouping is an important factor contributing to the induction of grouping, strengthening the case for an account that uses transitivity to explain induced grouping.

EXPERIMENT 1: INDUCED GROUPING VIA SIMILARITY

As noted, Experiment 1 used the *repetition-discrimination task*, which Palmer and Beck (2007; Beck & Palmer, 2002) proposed as a method to study grouping. In this task, subjects are asked to identify repeated elements in an otherwise alternating row. Grouping factors are manipulated such that some repetitions cross group boundaries (*between-groups* repetitions) and others occur within group boundaries (*within-group* repetitions). Figure 2 depicts two displays in which the repetition of interest involves shape. Subjects locate the repeated shape and indicate whether a square or circle is repeated. The principal finding in this task is that between-groups repetitions are identified more slowly than within-group repetitions. This effect may be due to greater difficulty spanning attention across groups as opposed to within a single group, as predicted by object-based theories of attention if groups are treated as objects at some level of visual processing (cf. Driver et al., 2001; Scholl, 2001).

Displays in Experiment 1 were composed of two rows of items, a target row and a distractor row (see Fig. 3a). The target row was similar to the rows in Figure 2, but with no grouping principle (except for shape similarity, which grouped only the target pair); the distractor row was a set of crosses. In the critical conditions, crosses were red and green, and grouped pair-wise by color; the *within-group* and *between-groups* conditions were defined by how the targets aligned with the pairs of crosses. Two control conditions retained the properties of the critical conditions local to the target items, so that any grouping effect observed could be compared with effects that occurred in the absence of grouping. In the *alternating* condition, red and green crosses alternated, and in the *uniform* condition, all the crosses were the same color. The design included a manipulation that modulated grouping

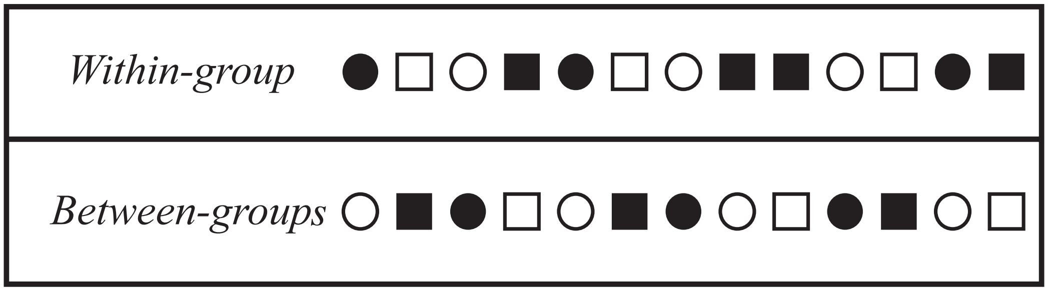

Fig. 2. Illustration of the repetition-discrimination task (Beck & Palmer, 2002). Observers are asked to search for the shape repetition in each display. Color similarity splits the items into pairs. Subjects are slower to identify repetitions that cross pair boundaries (between-groups condition) than to identify repetitions that occur within pair boundaries (within-group condition).

between the top and bottom rows, so that it could be verified that any effect observed was due to interset grouping: A long black line appeared either above the two rows or in between the top and bottom rows. The line served as a common-region cue (Palmer, 1992) that separated the space in the display, implying either that the two rows were in the same region or that they were in separate regions.

Method

Participants

Experiment 1 included 10 participants, who came from the Harvard University community and participated for pay or course credit.

Stimuli and Task

Displays were presented on a 17-in. monitor and consisted of a gray background with two rows of distinct elements. There were 15 items in the target row and 15 items in the distractor row; a black line was placed either just above or just below the target row (at a distance of 0.85° of visual angle from the center of the target row). The items in the target row were black squares and circles (0.67° × 0.67°). Each target row consisted of evenly spaced alternating squares and circles, with a single repetition of a shape. Center-to-center spacing of items within rows and columns was 1.7°. The position and identity of the repeated shapes were chosen at random. The distractor row was vertically aligned with the target row and consisted of evenly spaced colored, cross-shaped items the same size as the items in the target row.

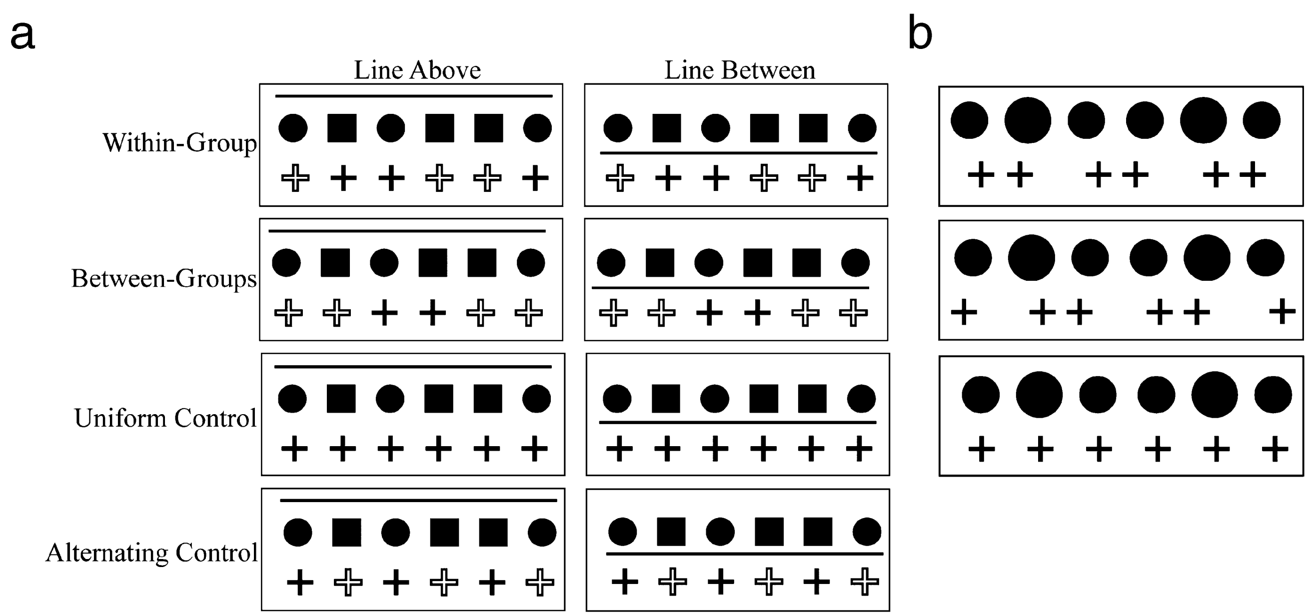

Fig. 3. Depiction of (a) the eight conditions in Experiment 1 and (b) the three conditions in Experiment 2a. Each display included a target row above a distractor row. In Experiment 1, the task was to locate the two adjacent target items that had the same shape, and in Experiment 2a, the task was to locate the two adjacent target items that were the same size. In the experiments, there were 15 items in each row (only 6 are shown here); the distractors were red or green (represented here by filled and outline shapes, respectively), and the target-row items were always black. See the text for details.

The task was to locate the repeated shapes in the target row and press a button as soon as they were found. A black *X* then replaced each target item, and the subject selected the positions of the repeated items with the computer mouse, verifying the choices with another key press. A 1,000-ms blank separated trials. Reaction time (RT) was calculated as the temporal difference between stimulus onset and the initial key press.

Conditions

Conditions (Fig. 3a) were determined by the placement of the black line and the color configuration of the distractors. In half the trials, the black line appeared above the target row; in the other half, the black line appeared between the target and distractor rows. This factor was crossed with four types of distractor configuration. In within-group and between-groups trials, the distractors were grouped pair-wise by color (red or green). In within-group trials, the target-row repetition was adjacent to two distractor items of the same color, whereas in between-groups trials, the repetition was adjacent to a group boundary. In the control conditions, the distractors were not grouped pair-wise by color. In the uniform condition, the distractor row consisted of all green or red items, and in the alternating condition, the distractors alternated in color.

Using an odd number of distractor and target elements ensured that there were equal numbers of within-group and between-groups positions on the top row, making structure of the distractor row uninformative.

Procedure

Participants completed 20 practice trials, then 40 trials for each of the eight conditions. Different conditions were presented in a randomly intermixed order, with breaks given to participants every 40 trials.

Results

Only RTs from trials on which subjects responded correctly were included in analyses. RTs greater than 5,000 ms and less than 150 ms were discarded to reduce the impact of outliers (this affected fewer than 1% of trials). Table 1 and Figure 4 present the mean RTs and standard errors.

RT and error data were entered into 2 (position of the black line) × 4 (distractor configuration) analyses of variance (ANOVA), which showed a significant interaction for RT, $F(3, 27) = 9.94$, $p < .001$, $\eta_p^2 = .486$, $p_{rep} > .99$, but no significant effects on accuracy (all *p*s > .05). Analyses of RTs within each of the line-position conditions yielded a significant effect of distractor configuration when the line was above the two rows, $F(3, 27) = 8.780$, $p < .001$, $\eta_p^2 = .494$, $p_{rep} > .99$, but not when the line was between the target items and distractor items, $F(3, 27) < 1$. Comparisons showed that when the line was above both rows, RT was slower in the between-groups condition than in any of the other three conditions (all *p*s < .02), and was 169 ms slower in the between-groups condition than in the within-group condition, $t(9) = 3.83$, $p < .005$, $d = 1.21$, $p_{rep} > .97$. Comparisons among the within-group and control conditions showed no significant variation (both *p*s > .17).

Discussion

This experiment demonstrates an RT measure of induced grouping. Induced grouping was observed despite the fact that the group-defining elements were distinct and irrelevant to the task, which implies that induced grouping was produced unintentionally. Critically, RTs were slower in the between-groups than in the within-group trials when the black line did not intervene between the target and distractor rows. This difference implies that participants had difficulty comparing items when they occurred in two different groups, relative to when they occurred in a single group defined by induced grouping. The sole effect was a slowing in the between-groups condition compared with all other conditions, despite the fact that local conditions were the same in the alternating condition as in the between-groups condition; Palmer and Beck (2007) observed a similar pattern in tests of basic grouping principles.

The inference that this effect reflects induced grouping was validated by the influence of the black line. The inclusion of the black line induced a segmentation of the screen into two separate regions. When the black line intervened between the two rows, the effect was expected to be reduced or eliminated

TABLE 1

Mean Reaction Times (in Milliseconds) in Each Experiment

	Experiment 1 ($N = 10$)				Experiment 3 ($N = 11$)		
Condition	Non-intervening line	Intervening line	Experiment 2a ($N = 13$)	Experiment 2b ($N = 20$)	Compatible targets and distractors	Incompatible targets and distractors	Digit-pair-search pilot study ($N = 8$)
Between-groups	1,205 (83.0)	1,073 (61.2)	1,702 (96.0)	1,725 (120.5)	1,335 (43.7)	1,334 (43.3)	1,341 (54.5)
Within-group	1,036 (69.2)	1,058 (72.9)	1,610 (80.3)	1,537 (90.1)	1,260 (39.1)	1,305 (34.5)	1,253 (63.3)
Uniform	1,086 (70.0)	1,064 (58.0)	1,592 (98.6)	1,550 (103.9)	—	—	1,385 (52.6)
Alternating	1,065 (70.0)	1,094 (62.8)	—	1,559 (90.2)	—	—	1,383 (101.9)

Note. Standard errors are given in parentheses. Data for Experiment 3 are collapsed into compatible (both rows were circles or both were crosses) and incompatible (one row was circles and one was crosses) conditions.

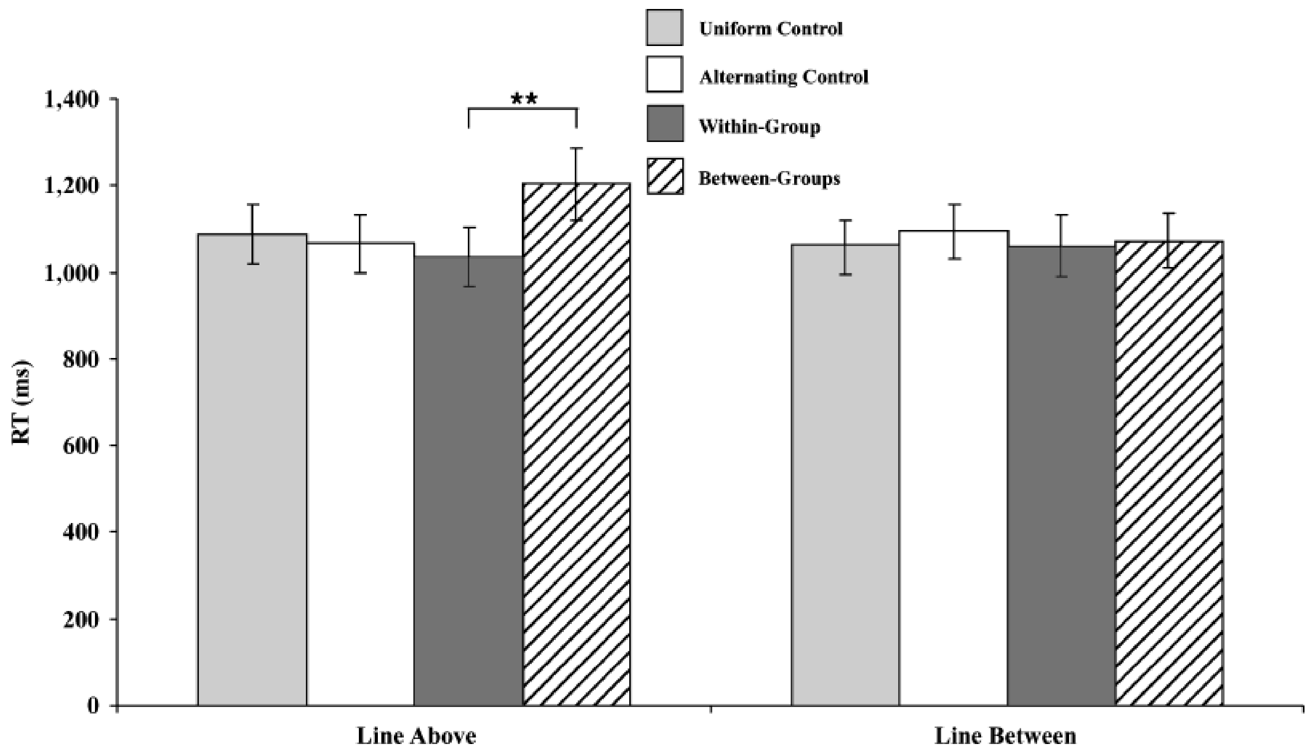

Fig. 4. Results from Experiment 1 (N = 10): mean reaction time (RT) as a function of condition. Error bars indicate standard errors. The asterisks indicate a significant difference between conditions ($p < .001$).

because of reduced strength of grouping between the top and bottom rows. Indeed, the intervening line eliminated the effect.

EXPERIMENT 2: INDUCED GROUPING VIA PROXIMITY AND COMMON FATE

To prove that induced grouping is a phenomenon that applies across grouping principles generally, it was critical to demonstrate that the effects observed in Experiment 1 could be produced by other grouping factors. Experiment 2 replicated the primary finding of Experiment 1, but with structure in the inducing row determined by proximity (Experiment 2a) or common fate (Experiment 2b).

Method

Except as noted, the parameters of this experiment matched those of Experiment 1.

Participants

Participants came from the Harvard University community and participated for pay or course credit. Experiments 2a and 2b included 13 and 20 participants, respectively.

Stimuli and Task

This experiment was simplified by excluding the black line in the displays. Target-row items were black circles alternating in size. Small circles were 0.68° in diameter, and large circles were 0.84°. The task was to identify size repetition, because difficulty was easier to calibrate with size than with shape discrimination. Distractor-row items were crosses that were all the same color, either red or green, on every trial.

Conditions

In Experiment 2a (see Fig. 3b), conditions were defined by the arrangement of distractor-row items. In the *between-groups* and *within-group* conditions, the distractor row was arranged such that the elements formed groups by proximity. Center-to-center distance was 1.0° for grouped distractors and 2.4° for ungrouped distractors. In the within-group condition, the center of a grouped distractor pair was vertically aligned with the center of the target pair (the repeated-size pair). In the between-groups condition, the center of no grouped distractor pair was aligned with the target pair. The *uniform* condition featured evenly spaced distractors.

In Experiment 2b, conditions were defined by movement of the distractors, which continuously oscillated upward and downward around the distractor positions in Experiment 1 (at 1.875 Hz). Range of motion was 0.68°. In the *uniform* control condition, distractors all moved synchronously and in phase. In the *alternating* control condition, distractors alternated such that adjacent items were out of phase. In the *between-groups* and *within-group* conditions, distractors were grouped pair-wise by common fate, such that grouped pairs moved synchronously and out of phase with adjacent pairs. Target pairs were aligned with the motion-defined groups in the within-group condition and were misaligned with the motion-defined groups in the between-groups condition.

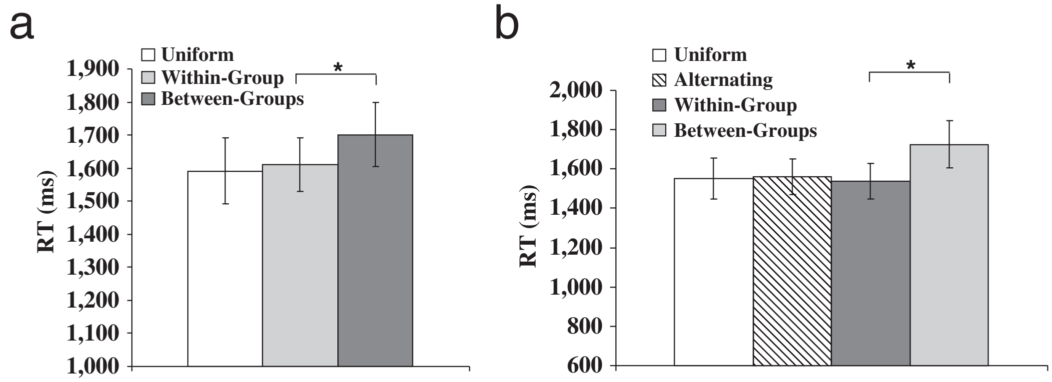

Fig. 5. Results from Experiments 2a (N = 13; a) and 2b (N = 20; b): mean reaction time (RT) as a function of condition. Error bars indicate standard errors. The asterisk indicates a significant difference between conditions ($p < .01$).

Results and Discussion

As in Experiment 1, only RTs from trials on which subjects responded correctly were included in analyses. RTs greater than 5,000 ms and less than 150 ms were discarded to reduce the impact of outliers (this affected fewer than 3% of trials). Table 1 and Figure 5 present the mean RTs and standard errors.

For both experiments, planned comparisons of the between-groups condition against the other conditions were conducted. In Experiment 2a, responses were slower in the between-groups condition than in the within-group condition, $t(12) = 3.14$, $d = 0.87$, $p < .01$, $p_{rep} > .95$, and were marginally slower in the between-groups condition than in the uniform control condition, $t(12) = 2.08$, $d = 0.57$, $p = .06$, $p_{rep} > .86$. RTs were not significantly different between within-group trials and uniform trials ($p > .65$). Condition had no effect on accuracy (both ps $> .4$).

In Experiment 2b, analyses of RT showed that responses were slower in the between-groups condition than in all three other conditions—within-group: $t(19) = 2.86$, $d = 0.64$, $p = .01$, $p_{rep} = .95$; uniform: $t(19) = 2.68$, $d = 0.60$, $p = .015$, $p_{rep} = .94$; alternating: $t(19) = 2.78$, $d = 0.62$, $p = .012$, $p_{rep} = .945$. Within-group RTs were not significantly different from RTs in either of the control conditions (both ps $> .68$). There were no significant accuracy differences among the conditions (all ps $> .15$).

As this experiment demonstrates, grouping due to proximity and grouping due to common fate spread from one set of items to another, affecting performance. These results confirm that the perception of grouped items influences the perception of target items so as to produce induced-grouping effects, regardless of the type of grouping cue that operates in the inducing set.

EXPERIMENT 3: INTERROW SIMILARITY AND THE DIGIT-PAIR SEARCH TASK

Experiment 1 demonstrated one instance in which the potency of induced grouping can be reduced by introducing a common-region cue that separates the inducing set from the uniform set. Experiment 3 was conducted to further examine the possibility that interset grouping is a critical factor in induced grouping. In Experiment 3, the similarity between the top and bottom rows was manipulated.[2] If the grouping of two rows is critical to producing induced grouping, then trials in which items in the two rows are highly similar should produce stronger induced-grouping effects than trials in which the interrow similarity is low.

A second aim of this experiment was to provide converging empirical evidence for induced grouping. The repetition-discrimination task may not be ideal for the study of "pure" induced perceptual grouping. Because the repeated pair in the target row is perceptually grouped, an observed difference between the between-groups and within-group conditions may be due to reinforcement of an existing group in the within-group condition, rather than the establishment of structure from grouping in a completely unstructured set.[3] Further, the locus of the effect (at perceptual, decision, or response stages) is questionable in the repetition-discrimination task: The target items always match, whereas all other pairs mismatch. Slowing may occur on between-groups trials because of competition at a response stage (i.e., trouble responding "same" when other local information conflicts), rather than difficulty in perceptually processing between-groups repetitions.

In the digit-pair search task used in Experiment 3, two numbers were cued; then, two arrays of target (unstructured) and distractor (structured) items appeared, much as in the prior experiments (see Fig. 6a). A small numeral was superimposed on each of the target-row items, and participants searched for the cued pair of digits on adjacent target items. This pair occurred on adjacent items only once, either within a group or between two groups, as defined by induced perceptual grouping. This task retains the requirement of spanning attention across elements that either do or do not belong to the same group, but without introducing any direct cue to grouping in the target row.

[2] I thank Stephen Palmer for suggesting this manipulation.

[3] I thank Brian Scholl for pointing out this concern.

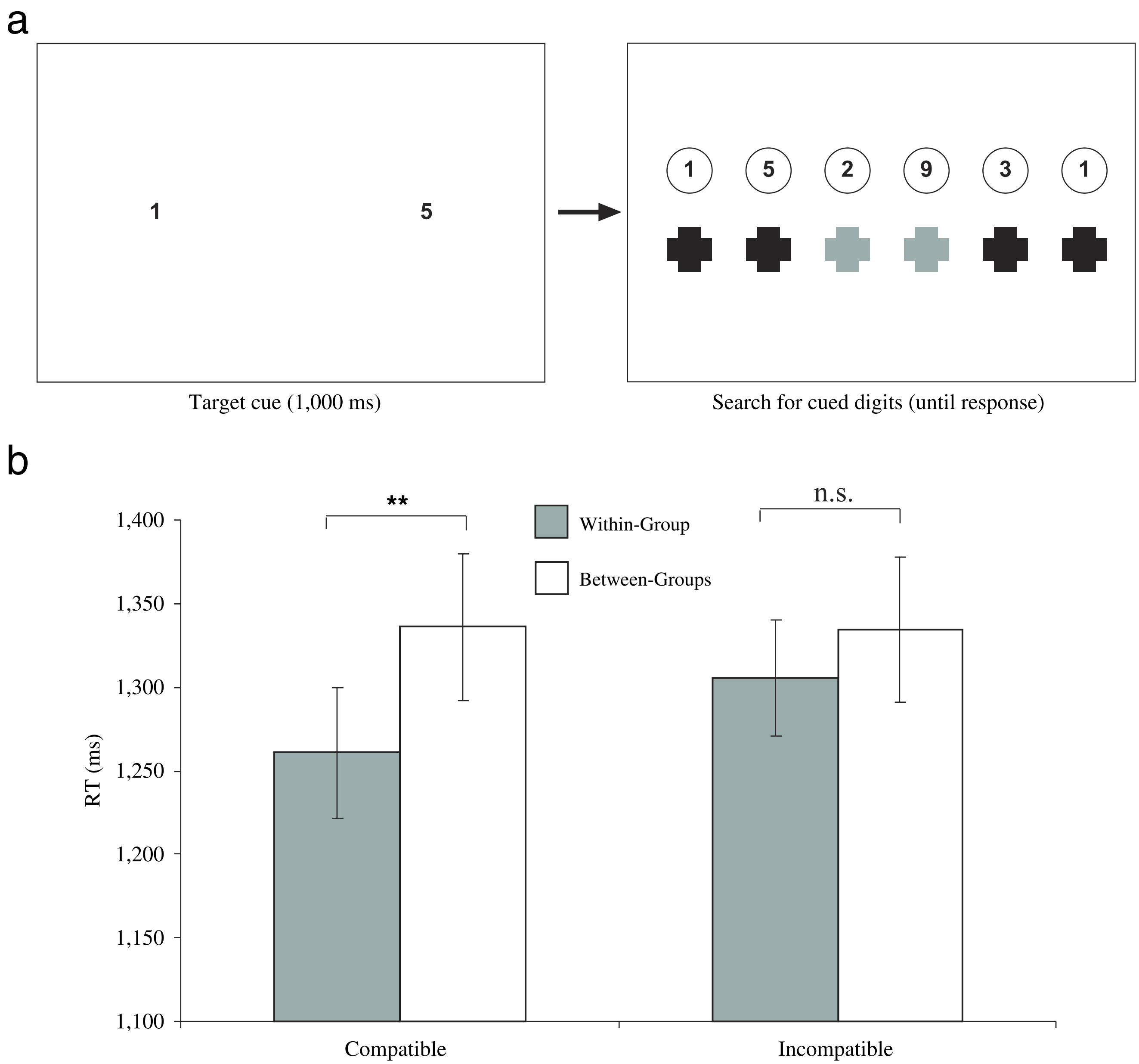

Fig. 6. Schematic depiction of a trial from Experiment 3 (a) and mean reaction time (RT) results (N = 11) as a function of condition (b). Participants were shown two numbers, then searched for those numbers in adjacent items in the subsequent display. In the compatible condition, the top and bottom rows were composed of the same shapes, and in the incompatible condition, the top and bottom rows were composed of different shapes. The illustration in (a) depicts an incompatible within-group trial. The actual number of items per row was 11. Error bars indicate standard errors. The asterisks indicate a significant difference between conditions ($p < .001$).

The suitability of this task was tested in a pilot study with a design similar to that of the compatible condition with circle targets in Experiment 3 (see the Method and Results sections), but with uniform and alternating control conditions included. This technique generated a pattern of RT differences similar to that obtained with the repetition-discrimination task (see Table 1), except that responses on within-group trials were speeded compared with responses on between-groups, uniform, and alternating trials (all ps $< .05$), none of which differed significantly from one another (ps $> .27$).

Method

Participants

Eleven subjects from the same study pool completed this experiment in return for pay or course credit.

Stimuli and Conditions

Each trial began with the presentation of the target cues: two large digits (1.7°) chosen randomly without replacement from the set of digits 1 through 9. These appeared on opposite sides of and 6.7° from the center of the screen. After 1 s, the cues were replaced by two rows of items, aligned one above the other (all items measured 1.7° across). The top-row items (targets) were 11 black circles or crosses with white numbers (0.4° × 0.4°) superimposed on them; the bottom-row items (inducers) were 11 red and green circles or crosses grouped pair-wise by color. Each item was spaced 2.3° from each of its neighbors. The cued pair of numbers occurred on neighboring items only once in every display, although every other digit was drawn randomly with replacement from the same set of digits 1 to 9, with the restriction that no two adjacent digits were identical. After the participant had located the cued numbers (adjacent and in the cued order), he or she pressed a button, and then the procedure continued as in Experiments 1 and 2. A 1-s blank preceded the onset of the next trial's cue.

Eight conditions were defined by crossing two positions of the target pair with respect to the induced grouping (within or between groups) with two target-row shapes (circle or cross) and two inducer-row shapes (circle or cross). Conditions were randomly intermixed for each participant, with a total of 40 trials in each condition.

Results

As in the previous experiments, only RTs from trials on which subjects responded correctly were included in analyses. RTs greater than 5,000 ms and less than 150 ms were discarded to reduce the impact of outliers (this affected fewer than 1% of trials). Table 1 presents the mean RTs and standard errors.

Initially, data were combined according to the compatibility of the targets and inducers. If both targets and inducers were circles or if both targets and inducers were crosses, then the trial was labeled a *compatible* trial; otherwise, it was labeled *incompatible*. Two predictions were tested. The first was that average RT would be slower in the between-groups condition than in the within-group condition. The second was that this RT difference would be larger for compatible than for incompatible trials, because the targets and inducers would be grouped more readily in the former. (Note that the accuracy data were tested in analyses analogous to the RT analyses reported in this section. At 98.1% overall, accuracy was very high, and no significant differences were found in any test, all $ps > .3$.)

RTs for the within-group and between-groups conditions were examined using a separate planned comparison for each of the two compatibility conditions (see Fig. 6b). Within the compatible condition, RT was significantly slower in between-groups trials than in within-group trials, $t(11) = 5.513$, $d = 1.66$, $p < .001$, $p_{rep} > .99$. Within the incompatible condition, the RT difference between the two grouping conditions was smaller and not significant, $t(11) = 1.307$, $d = 0.39$, $p = .22$, $p_{rep} = .70$. The corresponding interaction between compatibility and grouping condition was significant, $F(1, 10) = 10.408$, $p < .01$, $\eta_p^2 = .51$, $p_{rep} > .95$.

RTs were also analyzed for each combination of target and inducer shapes separately. When circles were the targets, a difference between the between-groups and within-group conditions was observed when the distractors were also circles (1,346 ms vs. 1,243 ms), $t(10) = 3.432$, $d = 1.03$, $p < .01$, $p_{rep} > .96$, but a weaker effect was found when the distractors were crosses (1,326 vs. 1,304 ms, $t < 1$). When crosses were the targets, a significant difference between the between-groups and within-group conditions was observed when the inducers were also crosses (1,342 vs. 1,307 ms), $t(10) = 3.34$, $d = 1.01$, $p < .01$, $p_{rep} > .96$, but not when the inducers were circles (1,326 vs. 1,279 ms), $t(10) = 1.2$, $d = 0.36$, $p < .26$. The interaction between target-inducer compatibility and grouping condition was significant for circle targets, $F(1, 10) = 10.41$, $p < .01$, $\eta_p^2 = .51$, $p_{rep} > .95$, but not for cross targets ($F < 1$). However, these results confirm that the differences between the compatibility conditions were not driven solely by one of the shapes.

Discussion

The digit-pair search task serves as a second empirical validation of induced perceptual grouping. Responses were slower when the target digit pair spanned a group defined by induced grouping than when the target digit pair was contained within a group. This result demonstrates that induced-grouping effects are not due solely to the reinforcement of a preexisting group, but can occur even when no low-level cue to grouping is provided in the set of target elements. A stronger effect was obtained when the shapes in the top row matched the shapes in the bottom row than when the shapes in the two rows differed. This compatibility effect confirms that interset grouping is critical to induced grouping.

GENERAL DISCUSSION

This study demonstrates induced perceptual grouping, a type of grouping that is due to the grouping of other items in the scene. The induced-grouping principle works like basic grouping principles in that if all else is held equal, induced grouping alone can determine which scene elements are grouped. The subjective demonstrations in Figure 1a and the experimental results show that induced grouping can occur on the basis of proximity, similarity, and common fate.

The induced grouping that observers report when informally polled about the stimuli in Figure 1a might be due to an intentional, imposed interpretation, but the experiments presented here show that induced grouping also occurs unintentionally, affecting performance when it is completely unrelated to the participant's task. In Experiments 1 and 2, induced grouping occurred unintentionally and affected performance in a repetition-discrimination task, whether the grouping principle applied to the distractor row was similarity, proximity, or common fate. All three of these intrinsic grouping factors spread from the row of distractors to the target row, affecting performance by slowing down responses when the repetition crossed an induced grouping boundary. Experiment 3 provided converging evidence from a novel paradigm, which did not introduce any extraneous grouping factor in the unstructured set.

Additionally, the importance of interset similarity in Experiment 3, and the reduction of the induced-grouping effect caused by an intervening line segment in Experiment 1, implies that interset grouping is an essential factor in inducing perceptual grouping. The importance of interset grouping strengthens the case for an explanation based on transitivity, which predicts that factors modulating the link between the structured and unstructured sets should modulate the degree of induced structure.

In conclusion, these demonstrations and experiments serve as proof of the importance of induced grouping. When grouping spreads, it links distant elements together, differentiating sets of items that are otherwise unstructured. Induced grouping affects performance when tasks require attending to multiple elements, a finding implying that induced grouping occurs unintentionally. Induced perceptual grouping hints at how the visual system constructs a complete percept, possibly by transitively or recursively applying grouping heuristics.

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