Associative grouping: Perceptual grouping of shapes by association

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Abstract

Perceptual grouping is usually defined by principles that associate distinct elements by virtue of image properties such as proximity, similarity, and occurrence within common regions. What role does learning play in forming a perceptual group? This study provides evidence that learning of shape associations leads to perceptual grouping. Participants were repeatedly exposed to pairs of unique shapes that co-occurred within a common region. The common region cue was later removed in displays composed of these shapes, while participants searched the display for two adjacent shapes of the same color. When the adjacent shapes with the same color came from the same trained groups, participants were faster at locating the color repetition than when they were composed of two shapes from different trained groups. The effects were perceptual in nature: learned pairings produced spatial distortions similar to those observed in groups defined by perceptual similarity. A residual grouping effect was observed even when shapes in the trained group switched their relative positions, but was eliminated when each shape was inverted. These results indicate that statistical co-occurrence with explicit grouping cues may form an important component of perceptual organization, determining perceived scene structure based solely on past experience.

Key words: perceptual grouping, associative learning, perceptual organization, visual statistical learning

Associative grouping: Perceptual grouping of shapes by association

A fundamental challenge of vision science lies in determining how humans detect and understand structure in the visual environment. Historically, the processes that create an organized percept have been seen as driven primarily by stimulus properties such as texture continuity, similarity and proximity of distinct elements, and the presence of cues to region and connectedness in the image (Wertheimer, 1923; Palmer, 1992; Palmer & Rock, 1994). Vision scientists have long viewed perceptual organization as a set of processes that precede object recognition and the operation of visual attention (e.g., Neisser, 1967; Marr, 1982; Treisman, 1982), and Gestalt psychologists especially viewed these processes as largely independent of experience (e.g., Wertheimer, 1923; Gottschaldt, 1926). However, some of these views have been challenged in recent years. For instance, Peterson and colleagues provided evidence that figure-ground segmentation, a fundamental component of perceptual organization, is profoundly influenced by knowledge of familiar shapes (Peterson, Harvey & Weinbacker, 1991; Peterson & Gibson, 1994). This learned influence on perceptual organization opens up the possibility that learning may also alter perceptual grouping of distinct visual elements, a notion taken for granted by recent theories of grouping (Roelfsema, 2006; Ullman, 2007). However, as reviewed below, empirical evidence for how learning affects perceptual grouping remains ambiguous. Here, we attempt to answer the question: “Can two shapes become so strongly associated through learning that they are unintentionally grouped?”

In this paper we address perceptual grouping, which must be distinguished from other perceptual organization processes, such as texture segmentation (resolution of a continuous region based on textural differences), and figure-ground segmentation (assignment of depth to elements of a scene that border one another in the image). Perceptual grouping binds together distinct elements that do not necessarily share borders in an image (Palmer & Rock, 1994). Perceptual space around the grouped items is warped (Coren & Girgus, 1980), and attention spreads within groups or preferentially selects grouped elements (Marino & Scholl, 2005; Dodd & Pratt, 2005). The outcome of perceptual grouping is a representation that is, on some level, treated as a whole by attention and perception, even though it clearly consists of distinct and often widely separated elements.

Previous demonstrations of experience effects in grouping

Recent evidence suggests that experience plays a significant role in some aspects of perceptual grouping. In the most direct demonstration to date of the importance of learning in grouping, Zemel, Behrmann, Mozer, and Bavalier (2002) asked participants to compare contour properties of object parts situated on opposite sides of an occluding bar. This comparison was faster when the parts were aligned and appeared to belong to the same object than when they were offset and seen as parts of different objects. However, some participants were trained in a session of the task in which the occluder was removed, and the unaligned elements were seen as part of the same object. This training changed participants' assumptions about the occluded shapes, and the unaligned parts were perceived as belonging to the same objects when the occluder was in place: these participants compared unaligned regions as quickly as aligned regions. Thus, learning altered the interpretation of amodal completion, by inducing observers to treat two widely separated image segments as part of a single object.

In another demonstration of the effects of experience on grouping, Kimchi and Hadad (2002) asked participants to judge whether two side-by-side letter shapes are the same or different. These shapes were preceded by another shape that was either the same as one or both targets, or unrelated (an array of random dots). Kimchi and Hadad found that a related prime sped up "same" judgments, both when the prime and targets were upright and when they were inverted. However, when the prime letter segments were constructed of disconnected segments, briefly presented primes facilitated later comparison only in the upright orientation for short prime-target intervals. Kimchi and Hadad suggested that past experience with upright letters enabled participants to quickly group segments together when they formed a letter. Lack of experience with inverted letters eliminated this grouping advantage.

Although the studies cited above have implied a role of learning in modulating perceptual grouping, we do not know whether such learning depends on the presence of amodal completion cues (as was the case in Zemel et al.'s study), and whether a short-period of training (as opposed to a lifelong experience with letters in Kimchi and Hadad's study) can affect perceptual grouping. The focus of the present study is to examine learned grouping among disconnected elements following a short learning period.

Evidence from illusory conjunctions

Prinzmetal and colleagues have examined a similar question to that posed by our study, using illusory conjunctions, which occur when features (e.g., color) of one object are inappropriately bound to features (e.g., shape) of another object (Treisman & Schmidt, 1982). Illusory conjunctions are more likely to occur within perceptual groups than between groups (Ivry & Prinzmetal, 1991; Prinzmetal & Keysar, 1989), and thus they have sometimes been used as an index of grouping. In an examination of the effect of experience on illusory conjunctions, Prinzmetal and colleagues found that illusory conjunctions of letter shape and color were more likely to be observed between elements of an orthographic unit than between elements of two different orthographic units (Prinzmetal & Millis-Wright, 1984; Prinzmetal, Treiman, & Rho, 1986). Thus, if illusory conjunctions are a correlate of grouping, these studies suggest that orthographic units group letters due to experience.

One concern about the learned-grouping inference arises from Esterman, Prinzmetal, and Robertson (2004). They found that semantic category affects illusory conjunctions: illusory conjunctions are more likely to occur between a letter or digit and an O-shaped stimulus if the O is contextually perceived as the letter O or digit zero, respectively. Thus, the unitization of words observed by Prinzmetal and colleagues might not occur at a perceptual level.

Another problem arises from the use of linguistic stimuli, which have the benefit of a lifetime of exposure, a correspondence with vocal stimulation, and associations due to a mixture of co-occurrence frequency and correspondence with Gestalt cues. They are also engineered and uncontrollable, and thus the combinations that produced illusory conjunctions may be confounded with other cues to grouping that determined their selection as linguistic units in the first place. Thus, no causal relationship between training and grouping effects was established by these studies.

These limitations are overcome in the present article. The meaningless nature of our stimuli and the fact that the groupings we induced were completely incidental to the task removed the semantic component from our findings. Our paradigm also allows the direct demonstration of a causal relationship between group training and transfer.

Visual statistical learning

Finally, our question also closely relates to those posed by researchers who study *visual statistical learning* (VSL). Fiser and Aslin (2001) found that participants could recognize shape pairs after short training sessions in which they were exposed to arrays of shapes that contained embedded statistical dependences (e.g., if shape 1 appeared in the scene, then shape 2 appeared in the scene, always in the same configuration). These shape pairs were recognized at above-chance levels, even though the training phase was passively viewed. In a similar vein, Brady and Kersten (2003) asked human subjects to observe scenes in which an object was embedded within a field of similar looking parts, such that the object was camouflaged. Repeatedly viewing such stimuli with the same objects embedded in different camouflaged fields led to significant improvements in both recognition and tracing accuracy. In addition to above-chance recognition of learned associations, participants can also use the association to facilitate performance in visual search. For example, Chun and Jiang (1999) showed that correlation between distractor and target shapes in visual search could be learned to speed up search on trained pairs.

Although VSL can result in recognition of learned associations, there is no evidence that the trained shapes are actually *perceived* as a single group. In principle, participants may be able to recognize shape associates without forming perceptual groups of them, and perceptual groups may form between items without explicit recognition of cues that lead to grouping. When perceptual grouping occurs (due to similarity, for example), the resulting group is treated by the visual system as a unit. However, it is hard to claim that grouped units are “recognized.”

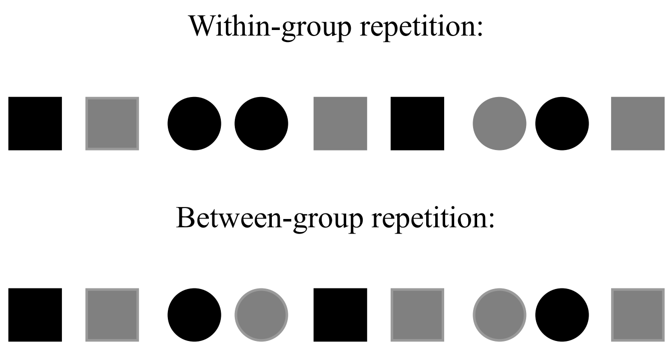

Figure 1. An example of the repetition discrimination task of Palmer and Beck (2007). The task is to find the repetition of color, and identify it as gray or black. When the color repetition does not coincide with the shape similarity grouping, repetition discrimination is slower than when it does coincide with the grouping.

<u>The present study</u>

In this study we ask whether visual training can ever lead to perceptual grouping of unconnected, distinct elements. Traditionally, perceptual grouping has been measured by subjective report of grouping (Kubovy & Wagemans, 1995), which unfortunately may be insensitive to short periods of training. As reviewed above, perceptual grouping is also sometimes measured by asking participants to recognize the group or to trace the foreground object from camouflage (e.g., Brady & Kersten, 2003), but recognition does not necessarily imply grouping. An alternative measure to subjective report and recognition has been developed recently by Palmer and Beck (2007), using a paradigm called the "repetition discrimination task" (RDT; see also Beck & Palmer, 2002; Vickery, 2008). In this paradigm (Figure 1), participants view a row of items that are grouped by one dimension (such as shape similarity). Participants are asked to locate two adjacent items that are the same in another dimension (such as color). Color repetition detection is faster when the repeated items belong to a single group than when they cross a group boundary on an irrelevant dimension. This effect is a desirable metric of grouping, because it is impartial and completely unintentional: exploiting the grouping factor cannot lend a performance advantage to the participants.

Another measure of grouping, less commonly used, relies on distortions of spatial perception caused by grouping. Coren and Girgus (1980) examined spatial distortions due to various rules of grouping. They asked 94 observers to estimate the distance between two dots. On grouped trials, the dots were grouped together by one of several traditional principles. On ungrouped trials, the two dots belonged to different groups, but had the same spacing as on grouped trials. Participants judged the grouped dots as closer than ungrouped dots, despite the equivalence of their spacing. Thus, grouping can be assessed by examining the extent to which spatial distortions occur.

A. B.

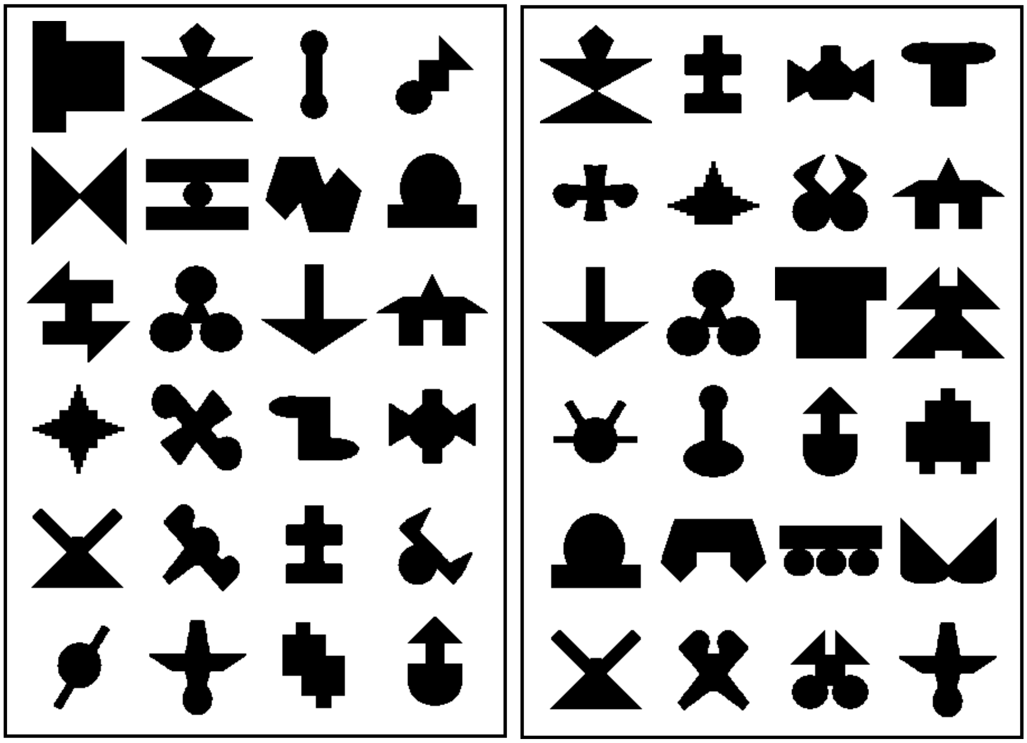

Figure 2. a.) The set of shapes used in all but experiment 3 (from Fiser & Aslin, 2001; and Turk-browne, Jungé, & Scholl, 2005). b.) Vertically asymmetric shapes used in experiment 3, composed of some shapes from A, plus additional ones created for this study.

In the experiments presented here, we trained subjects on pairings of the stimuli shown in figure 2, then tested them in a transfer procedure in which the task was to detect a repetition of color (an example trial is shown in figure 3B), or to adjust the spacing between grouped and ungrouped pairs. If associative learning supports grouping, then in the RDT transfer task, participants should be slower to detect a repetition of color if the repetition crosses a learned group boundary than if it occurs within a learned group. In the distance adjustment task, participants should show similar distortions of spatial perception due to trained grouping as with traditional grouping principles.

In this paper, we first identify a case in which associative grouping occurs, and then explore some of its properties. Experiment 1 serves as an existence proof of this form of learning, in which pairs of shapes become associated by an explicit grouping cue during a training phase, with residual grouping effects in the transfer phase. Experiment 2 confirms our findings by demonstrating that the trained grouping led to a spatial distortion effect. Experiment 3 examines two questions: 1.) How durable are these representations? 2.) Are these representations flexible to inversions of the original, learned shape pairs? Experiment 4 takes a closer look at the question of durability, asking whether the dissipation of learning over time is due to decay or interference. Finally, experiment 5 re-examines the flexibility of this learning, and asks whether grouping survives when the original learned shapes exchange positions.

Experiment 1: Transfer of a grouping effect based on shape association

To motivate the training approach used in this paper, it is useful to return to the ecological considerations introduced earlier. The binding of unique shapes into groups by association might be dominated, in the real world, by other, more powerful grouping cues, in particular common fate and connectedness. Ecologically speaking, grouping-by-association might come into play when these cues are ineffective. Thus, in the majority of experience, “bottom-up” grouping cues dominate scene understanding of groups and units. However, associative grouping would play a role when those cues are invisible due to accidents of viewpoint, lighting, and so on. Taking these factors into consideration, the acquisition of groups might be limited to those situations in which *both* statistics and visible grouping cues link together distinct stimuli.

In experiment 1, we tested the hypothesis that associative grouping might be observed when training included visible grouping cues. In the training phase, subjects complete a repetition localization task (Palmer & Beck, 2007), in which they searched through rows of shapes to find the repetition of color (two items that were side by side and had the same color), with pairs of shapes surrounded by common region (Palmer, 1992). These cues always surrounded the same shapes. That is, if a row was composed of shapes A, B, C, and D, then whenever these shapes were seen, A and B were grouped, and C and D were grouped. Afterwards, they completed a transfer phase that was similar to the training phase, but with the common region cue removed. If perceptual grouping is insensitive to learning, then there should be no difference in reaction time to detect a repetition of color that crosses shapes BC or DA than when it is contained within AB or CD. Alternatively, if perceptual groups can form due to statistical association of shapes, then between-groups repetitions of color (over BC or DA) should be slower than within-group repetitions (AB or CD).

Method

Participants. Seven individuals completed experiment 1. Participants in this and all other experiments were between the ages of 18 and 35, and drawn from the Harvard University community through the Department of Psychology's study pool (except in experiment 2). Participants completed approximately one hour of testing, for cash payment or course credit.

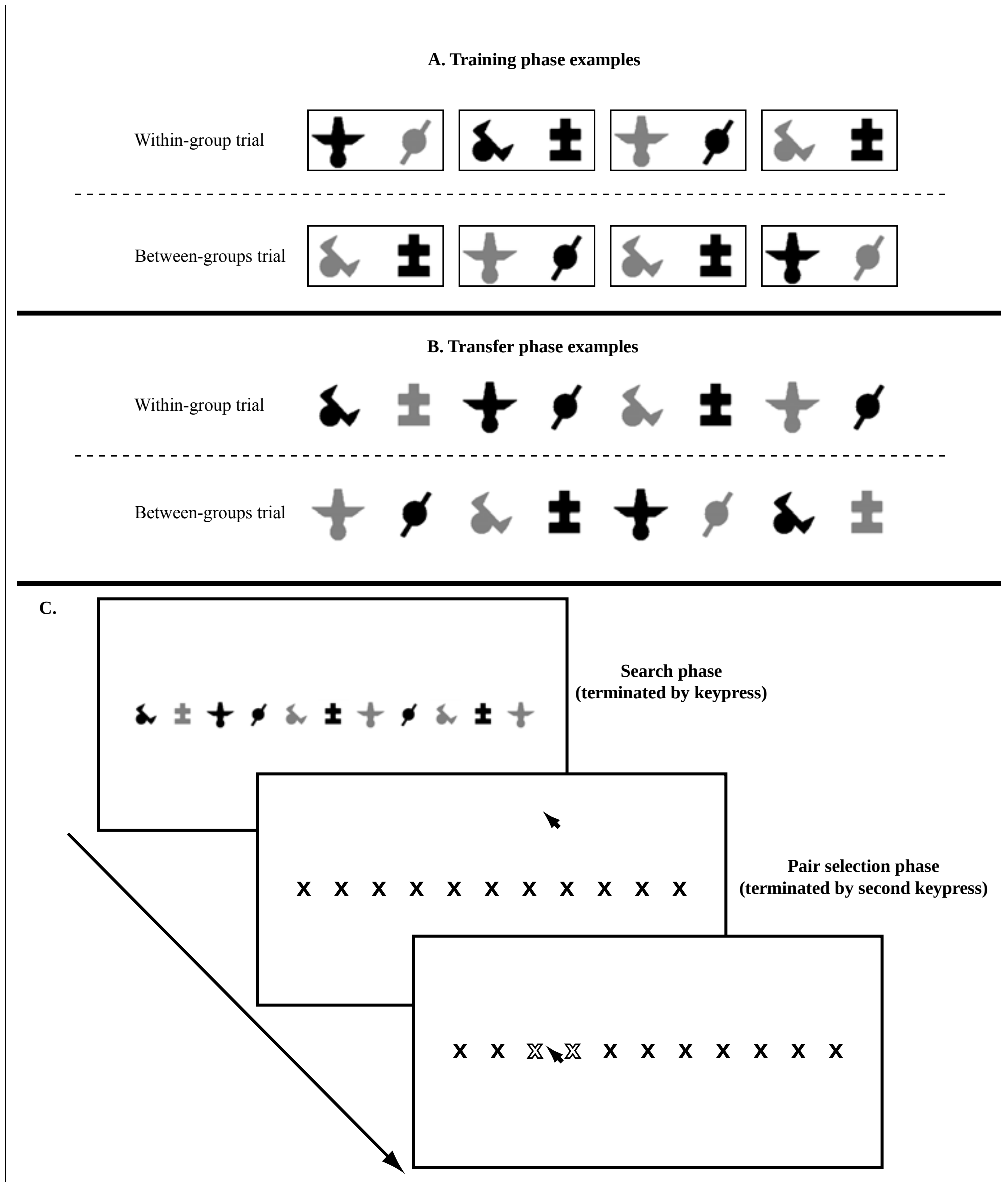

Figure 3. Experiment 1: Examples of training and transfer phase trials in within and between conditions. A. In the training condition, shape pairs were consistently grouped by common region. B. In the transfer condition, the boxes were removed, but shapes were still consistently paired. In the actual experiment, 15 items total were present in training, while 11 items were present on each trial of transfer. For simplicity, 8 are shown. The first shape was randomly chosen, and could be any of the 4 shapes that composed the scene. In training, one box had an empty "slot" due to the odd number of targets. C. A depictive example of a transfer trial for experiment 1. A different procedure, requiring only an identification response, was used in later experiments (not shown).

Stimuli. Shape stimuli were 24 unique shapes adapted from Fiser & Aslin (2001) and Turk-browne, Jungé, and Scholl (2005) (figure 2A). They appeared in white or light gray on a medium gray background (illustrated throughout this paper as black or gray on a white background, for the sake of depiction). Size varied slightly, but each shape was approximately 1.33° of visual angle on a side. For each subject, these shapes were randomly allocated to 12 pairings (henceforth, the "trained groupings") before the training period began.

Training Phase. The training phase of experiment 1A was a variation of the repetition discrimination task described above (figure 3A). Prior to the training phase, trained groupings were assigned to 6 configurations. That is, each trained pairing was assigned to another trained pairing. On each trial, a row of 15 evenly spaced shapes appeared, with each item spaced 1.7° center-to-center from its neighbors. Each of these shapes was from one of the six configurations, and they were arranged such that the shapes from trained pairs were adjacent. For example, if AB and CD were assigned to a configuration, then an example trial configuration would be CDABCDABCDA. The starting shape for each trial was chosen at random. Finally, a black rectangular contour (1.4º by 3.2º) surrounded pairs of shapes that were assigned to the same group. For example, black contours would surround AB and CD every time the above configuration was viewed.

Participants, however, were asked to ignore shape and the contours, and concentrate on color. Color normally alternated from left to right (dark, light, dark, light, …, with the first color chosen randomly). However, in every trial, two and only two neighbors shared the same color (a dark-dark repetition, or light-light repetition). The participant's task was to locate this repetition and press the space bar. The items were immediately replaced by black, X-shaped placeholders that masked the stimuli. Participants were told to position the mouse over the placeholders that were located in the same positions as the repeated items, click the mouse button, then verify their choice with another keypress (choices could be corrected before the final keypress). They were instructed to do this as quickly as possible without making an error.

The positioning of the color repetition was the key variable. On half the trials, the repetition was *within-group*, and was contained within a grouping (e.g., AB or CD, in our example). On the other half of trials, it was *between-groups*, crossing a grouping boundary (e.g., BC or DA), as defined by the common region cue.

During the training phase, participants completed 240 trials, broken into blocks of 40 trials. There were a total of 120 within-group and 120 between-groups trials, split evenly amongst the 6 possible shape pair combinations. Thus, participants were exposed to each possible shape pairing exactly 40 times.

Transfer phase. The transfer phase (figure 3B) was conducted immediately following the training phase, and was the same except for the following differences. First, the common region grouping cues were removed. Secondly, there were 11 items per row, compared to 15 during training (in order to reduce RT variance).

Participants completed four random practice trials, then 120 trials. Each trial was separated by a 1 s blank period. Each configuration appeared in 20 trials, composed of 10 *within-group* and 10 *between-groups* trials. Trials occurred in a random order and were divided into blocks of 40 trials, between which a short break was permitted. A beep indicated when an error was made. Participants were simply told that the task was identical, except that the boxes would not be present on the display and fewer items would be present.

The transfer phase of experiment 1 was designed to probe whether or not the learned pairs of shapes were perceptually grouped due to their statistical association in the training phase. A grouping effect in the training phase was expected (*between-groups* slower than *within-group* trials). But would this effect persist when the cues to grouping were removed?

Results

Training phase. Training phase results were analyzed by binning all trials into *between-groups* and *within-group* conditions, based on the location of the color repetition with respect to the trained shape pairs. RTs were analyzed, in this and in all future experiments, by first removing all incorrect trials. Then, RTs that were longer than 10 seconds were removed from analysis, to reduce the influence of outliers on the mean. Finally, RTs were averaged separately for each condition and each subject.

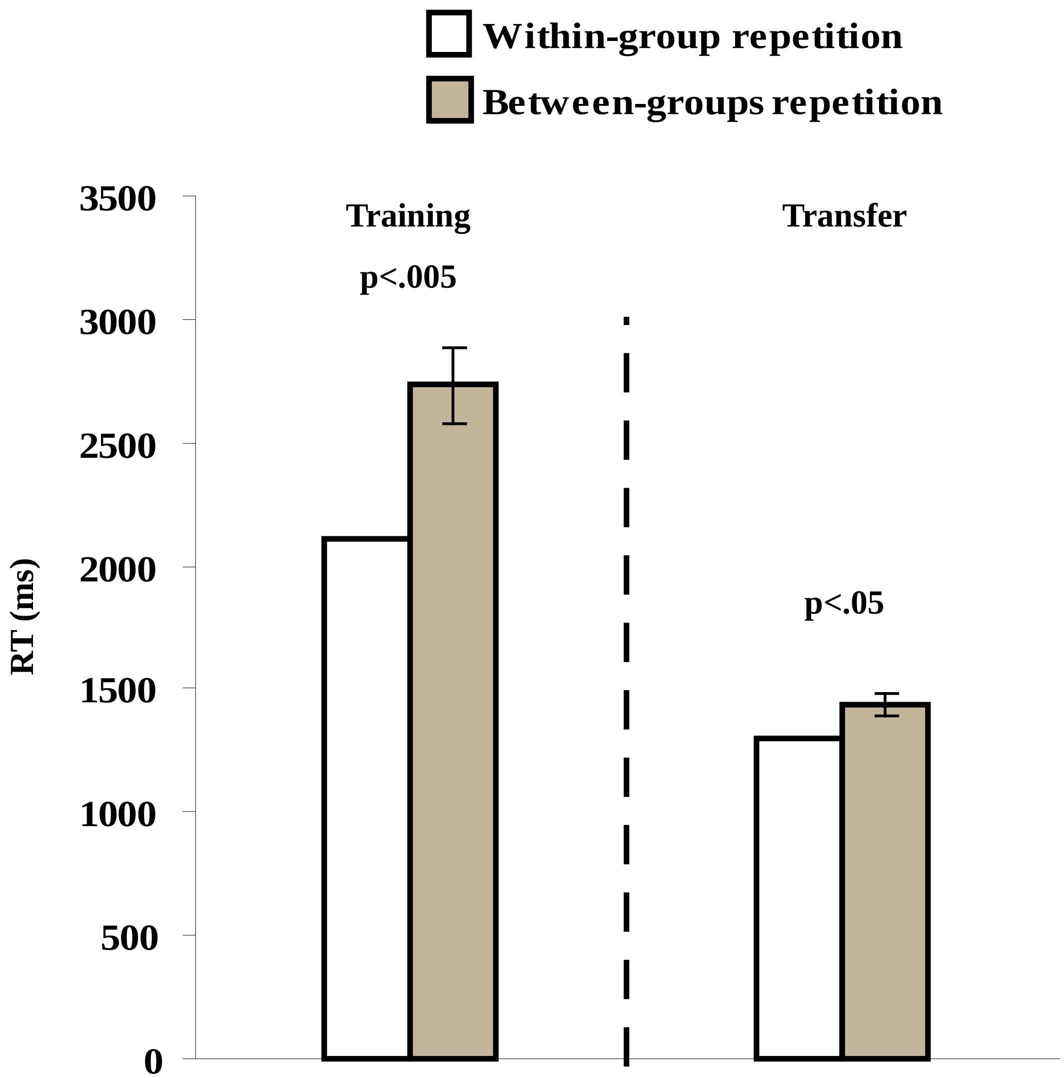

Figure 4. Results of experiment 1. Bars represent the RT in *between-groups* trials and *within-group* trials in training and transfer phases. The graph on the left depicts the result of the training phase (with boxed items), while the graph on the right depicts the result of the transfer phase (with no box cues to grouping). Error bars represent the standard error of the mean differences between adjacent bars.

For the training phase, analysis of accuracy showed that participants were highly accurate, and accuracy did not differ between the two grouping conditions (97.9% in the *within-group* condition and 97.3% in the *between-groups* condition, t<1).

The resulting RT analysis (Figure 4) comparing the 120 within-group trials to the 120 between-groups trials showed significant effects of the grouping cue, as predicted. Average RT on *within-group* trials was faster than on the *between-groups* trials, $t(6) = 4.32$, $p < .005$, $d = 1.63$. Thus, our common region grouping cue was effective at producing strong, measurable effects on reaction time in the RDT paradigm.

Transfer phase. RT analysis of the transfer stage was conducted in the same manner as RT analysis for the training stage, with the exception that a lower cutoff of 7 seconds was used in trimming outliers, since the decreased number of items and removal of boxes dramatically sped RT overall.[1]

In the transfer phase (Figure 4), between-group detection was also slowed significantly relative to the within-group condition, $t(6) = 3.10$, $p = .02$, $d = 1.17$. Analysis of accuracy showed that participants were on average less accurate on *between-group* (95.4%) than *within-group* trials (97.2%), although this difference was not significant, $t(6) = 1.93$, $p = .10$, $d = .73$, and this accuracy difference was in agreement with the RT grouping effect (i.e., worse for *between-group* than *within-group* trials).

Discussion

Experiment 1 provides the first demonstration that a grouping-like effect can be induced by incidental exposure to associated shapes. Interestingly, the introduction of a grouping cue induced a grouping effect even though attention to the shape features of the paired items was neither required nor helpful in performing the task. To distinguish this

[1] RT cutoffs used throughout (10 s for training, 7 s for transfer) were arbitrary and were meant to remove unreasonably long RTs based on the range of RTs observed in pilot data. In Experiment 1, the 7 s trimming procedure did not eliminate any trials. Trimming by a different method (by eliminating RTs that were more than 3 s.d. from the cell mean for each subject) did not significantly alter the results observed in these experiments.

from standard VSL, we term this form of learning *associative grouping*. We propose that associative grouping binds two objects together after cues that normally group them together are erased, and may form an important component of everyday perception. The rest of this paper verifies and expands upon some important properties of this effect.

Although the training and transfer phases differed in the number of items, and thus are not directly comparable, it does appear that the interference effect of the grouping cues was much reduced in the transfer phase. This is not unexpected, as grouping should be viewed as a combination of many factors. The common region cues are a very potent cue to grouping. The association of shapes was due to this cue, and thus any residue transfer effect would be less than or equal to this effect. On top of this, the presence of such a potent cue likely dominated effects of shape similarity that randomly occur between adjacent, ungrouped items. It is not surprising that the association of shapes due to such short training episodes would be less likely to dominate the "natural" grouping factors.

Experiment 2: Distortions of spatial perception due to grouping

Experiment 1 showed that one correlate of perceptual grouping can transfer from a training context in which a grouping cue consistently binds shapes together to a context in which no grouping cue is evident. The association was based on shape-identity. However, two caveats remain. First, given that the repetition-detection task was used in both training and transfer, it is possible that the effect shown in experiment 1 is task-specific, rather than a general one.[2] Secondly, the effect shows that a performance-based correlate of grouping can be influenced by trained associations, but is the effect truly

[2] We thank Mary Peterson for raising this question.

"perceptual"? In this experiment we show that such training can cause perceptual distortions that are similar to those caused by traditional grouping principles, and that these learning effects transfer across very different tasks.

As previously described, Coren and Girgus (1980) found distortions of spatial perception in grouped items, relatively to ungrouped items. However, Coren and Girgus' technique required many subjects, and showed weak effects that would be expected to be even weaker for grouping based on short, lab-based training episodes. Therefore, we developed a new paradigm inspired by their findings. Our technique involves the adjustment of distance between two items to match the distance between a reference pair. Experiment 2A validated this paradigm using the grouping cue of similarity, finding a consistent difference between adjustments to a grouped pair with respect to an ungrouped pair compared to adjustments to an ungrouped with respect to a grouped pair. We then employed the same technique in experiment 2B in the transfer phase, after participants were trained using the same group training regimen that was used in experiment 1.

Method

Participants. Participants were age 18 to 35, drawn from paid participant pools at the University of Minnesota and Yale University. 12 individuals completed experiment 2A and 9 participants completed experiment 2B.

Stimuli. The same shapes were used in experiment 2 as in experiment 1. In experiment 2A, however, the shapes were either light gray or black, rather than dark gray. In experiment 2B, they were identical to experiment 1.

a.
b.
c.

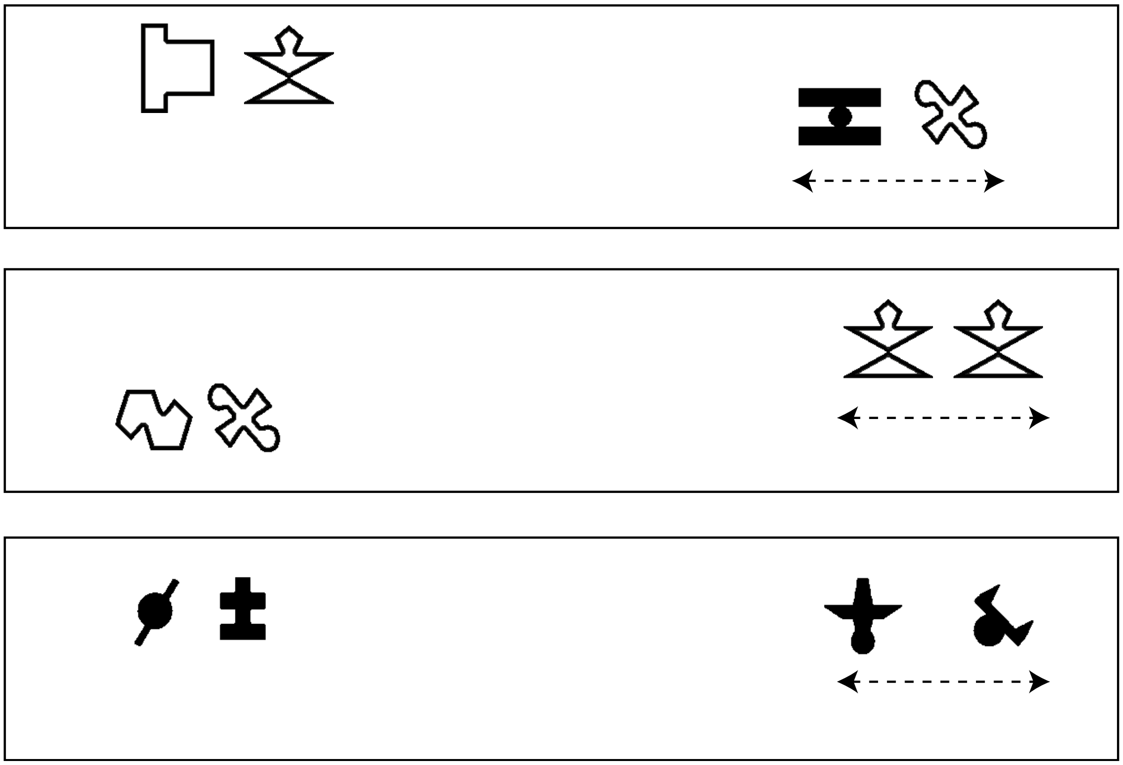

Figure 5. Examples of trials from experiment 2. Participants adjusted the distance between shape pairs on the right to match the distances between shape pairs on the left. The arrows were not shown. a.) A color-similarity *grouped-reference* trial. b.) A shape similarity *grouped-adjustment* trial. c.) An example trial from experiment 2B.

Experiment 2A Task and Procedure. In experiment 2A, participants saw two pairs of shapes on each trial. Examples are shown in figure 5. The pair on the left was always the *reference* pair, while the pair on the right was always the *adjustment* pair. The participant's task was to adjust the center-to-center spacing of the adjustment pair to match the center-to-center spacing of the reference pair. This was accomplished by pressing arrow keys, one of which moved the adjustment pair closer together by 1 pixel (0.034°), while the other key moved them apart by 1 pixel. Judgments were unspeeded and there were no constraints on the number of possible adjustments in a single trial. A final button press signaled that they were satisfied with the adjustment. The items in the *reference* pair were always separated 1.7° center-to-center (50 pixels). The items in the *adjustment* pair had a random initial separation between 1.4° and 2.0° (41 pixels to 59 pixels), although the initial separation never precisely matched the reference pair. Pairs were centered vertically, and position 15.6° (400 pixels) apart. However, both horizontal and vertical positions of each pair were also jittered independently in a 3.9° (100-pixel) window around these positions on a trial-by-trial basis.

In experiment 2A, two factors were manipulated. The first was whether the reference pair or the adjustment pair was grouped according to similarity. On *grouped-reference* trials, the reference pair was grouped by similarity, while the adjustment pair was not. On *grouped-adjustment* trials, the reference pair was not grouped, while the adjustment pair was grouped. The second manipulation was of the type of similarity grouping: color or shape. The shapes constituting the reference and adjustment pairs for a given trial were drawn without replacement from the set of shapes used in experiment 1. On *color-grouping* trials, the shapes in the grouped pair were the same color (both black or both light gray), while the shapes in the ungrouped pair were different colors (one black and one gray, chosen randomly). All of the items were differently shaped. On *shape-grouping* trials, the shapes in the grouped pair were identical, while the shapes in the ungrouped pair were different (from one another, as well as the grouped pair shape). Their colors were all light gray or all black, chosen randomly. Participants completed 24 trials in each of these four conditions, for a total of 96 randomly intermixed trials.

Experiment 2B Task and Procedure. Experiment 2B was composed of a training and a transfer stage, like experiment 1. The training stage was the same as in experiment

1, except instead of localizing the repetition and then clicking on placeholders in those positions, the task was instead to locate the repeated color and respond with one key if the repetition was composed of two dark items and another key if the repetition was composed of two light items. Response times and accuracy were based on these key presses.

The transfer stage was identical to experiment 2A, except where noted. First, groups were defined by the training stage pairings. “Ungrouped” pairs were drawn from pairs of shapes that appeared adjacent to one another during training, but separated into different groups by the common region grouping cue. “Grouped” pairs had appeared within the bounds of the same common region cues during training. For each transfer-stage trial, the grouped pair and the ungrouped pair had not appeared in the same configurations during training. Each of the 12 grouped pairs appeared four times during transfer, once in a *grouped-reference* and once in a *grouped-adjustment*. Each grouped pair appeared with two different ungrouped pairs, once in each of the two conditions. Thus, a total of 24 *grouped-reference* and 24 *ungrouped-reference* trials were completed, in a randomized order.

<u>Results.</u>

Experiment 2A. For each subject, the final spacing of the adjustment was averaged for each trial, separated by grouping condition (grouped-reference or grouped-adjustment), and type of grouping (color or shape similarity). These values were entered into a 2x2 repeated-measures ANOVA. There was no significant interaction ($F(1,11) = 1.8$, $p = .2$), and no main effect of grouping type ($F < 1$). However, there was a highly significant effect of reference-group assignment ($F(1,11) = 33.1$, $p < .001$), such that on *grouped-reference* trials, subjects adjusted the ungrouped pair to be farther apart than their adjustment of the grouped pairs on *grouped-adjustment* trials. Participants adjusted pairs to an average of 51.5 pixels (SEM = 0.35; degrees: Mean = 1.75, SEM = 0.012) apart on *grouped-reference trials*, and 50.0 (SEM = 0.38; degrees: Mean = 1.7, SEM = 0.013) pixels apart on *grouped-adjustment* trials. In both cases the reference pair was 50 pixels apart. Thus the participants were less accurate on *grouped-reference* than *grouped-adjustment* trials, and tended to adjust the non-grouped pairs to be farther apart than the reference, grouped pair. The effect was highly reliable for both *color* and *shape* similarity ($p < .005$ for both, post-hoc comparisons). These results suggest that perceptual grouping warps the space around grouped elements.

Experiment 2B. Training phase. Results of the training phase were similar to those of experiment 1. Participants were much slower to identify the repetition when it crossed a group boundary (3,313 ms) than when it was contained within a group boundary (2,624 ms; $t(8) = 15.6$, $p < .001$). There was no corresponding difference between accuracy ($t < 1$; average 97% accurate).

Transfer phase. In the transfer phase of the experiment, participant adjustment choices based on trained groupings showed a similar pattern to those observed with similarity-grouping. On *grouped-adjustment* trials, participants adjusted the grouped pairs to an average distance of 51.0 pixels (SEM = 0.77; degrees: Mean = 1.73, SEM = 0.026), compared to an average adjustment distance of 50.0 pixels (SEM = 0.73; degrees: Mean = 1.70, SEM = 0.025) for ungrouped pairs on *grouped-reference* trials, a difference that was observed in all participants and significant ($t(8) = 3.43$, $p < .01$).

<u>Discussion</u>

Both similarity grouping and trained grouping led to a similar pattern of spatial distortions in perception. This experiment bolsters support for our claim that the residual repetition discrimination effect observed in experiment 1 was due to perceptual grouping, per se. Two key issues are resolved by this experiment. For one, experiment 1 leaves open the possibility that the effect was task-specific, since the transfer task matched the training task, and thus the effect may not have been a general one. In experiment 2B, a grouping effect transferred between two completely different tasks – a color repetition task and a distance approximation task. Secondly, the first experiment showed a priming effect, but was it due to distorted perception? Experiment 2B suggests that spatial perception is distorted in a similar way for trained groups as it is for grouping by factors such as similarity.

The particular pattern of results observed in experiment 2A is curious. One might expect a different result based on those found by Coren and Girgus (1980). They found that participants judged the distances between grouped items to be larger than the distances between ungrouped items, all else held equal. Thus, we might expect to see the ungrouped pairs adjusted to be closer together than reality dictated on *grouped-reference* trials. However, their methods were quite different from ours. While our experiments involved adjusting one pair of items to match another, theirs involved marking a line with an approximate distance. While our experiments involved complex shapes, theirs involved small dots. One possible explanation for our results is that the distortion due to grouping was perceived by the observers, who overcompensated for it by moving the ungrouped pair to be farther apart than the real spacing. Another possibility is that, by asking our participants to approximately match the *center-to-center* distances between two objects, we focused attention on a different aspect of the grouped pairs, such as the internal structure of the bound unit. This might actually be perceived as larger in grouped than ungrouped pairs of items. A great advantage of our paradigm over Coren and Girgus' technique is that it was highly consistent across observers and produced very strong results with a much smaller sample size. Thus, whatever the final interpretation, this method could prove useful in the future and it should be investigated further.

Experiment 3: Flexibility and durability of associative grouping

Following up these results, we next probed the flexibility of associative grouping, and its durability. In experiment 3, we asked how specific this shape association learning was to the original presentation of the shapes and how durable it was to longer periods of exposure to these shapes following the removal of grouping cues. Specifically, we tested flexibility to inversions of the originally learned shapes, using a new set of 24 shapes (figure 2B) that were symmetric over the vertical axis and asymmetric over the horizontal axis (including several from the original set that met these qualifications). This manipulation was intended as a probe into the relationship of shape recognition processes to associative grouping. Shape recognition is known to be strongly orientation-dependent for shapes that are learned in a canonical orientation (e.g., Jolicoeur, 1985). If associative grouping depends on shape recognition processes, then inverting the shapes from the learned, canonical orientation would be expected to disrupt recognition and reduce the strength of associative grouping. If, however, associative grouping depends on associations between orientation-independent features of the shapes, then the learning effect might be expected to survive inversion.

In our experiment, we assigned one set of subjects, the *same shape* group, to the standard training and transfer conditions introduced in experiment 1. A second set of subjects, the *transformed shape* group, received standard training procedures, but saw transfer-phase displays composed of shapes that were turned upside down compared to their training-phase presentations. We also doubled the length of the transfer phase in both groups, in order to investigate the durability of the associative grouping effect.

Method

Other than the noted modifications, all procedures were identical to those in experiment 1.

Participants. Participants were 38 individuals from the same population, randomly assigned to 2 separate groups of 19 subjects, each.

Stimuli. A new set of 24 shapes was constructed. These shapes were similar to those used in experiment 1 (and included some of the same shapes), but their forms were all symmetric about the vertical axis, and asymmetric about the horizontal axis (see figure 2B).

Design. We tested two groups of participants. For one group, the *same shape* group, the training and transfer sessions were identical to experiment 1, except that the new stimulus shapes were employed, and the duration of the transfer phase was doubled to 240 trials (split into two 120-trial epochs for analysis). For the second group (the *transformed shape* group), the training session was identical to the *same shape* group, but in the transfer session, the stimuli were inverted (turned upside-down).

Half of the subjects in each group were trained with the stimuli oriented as in figure 2B, while the other half were trained with vertically inverted shapes (actually, 10 and 9 subjects received each manipulation, respectively). Thus, any difference between the two groups at transfer could not be due to the shapes being in one or the other orientation.

Results

*Training phase***.** Training phase results were consistent with those of experiment 1, with no differences evident between the two participant groups. Neither group showed a significant effect of grouping condition (*within-group* compared to *between*-groups) on accuracy during training (both $p>.3$). Both groups showed a significant effect of the grouping factor on RT. For the *same shape* group, average RT on *between-groups* trials was 3,025 ms, compared with 2,400 ms on *within-group* trials, $t(18) = 8.37$, $p < .001$, $d = 1.92$. For the *transformed shape* group, average RT on *between-group* trials was 3,110 ms, while RT on *within-group* trials was 2,519 ms, $t(18) = 7.85$, $p < .001$, $d = 1.82$. A mixed-factor ANOVA showed no group x grouping condition interaction, $F<1$. Thus, the two groups showed statistically indistinguishable effects of the grouping cues during training.

Transfer phase. A series of planned comparisons on transfer-phase accuracy and RT were conducted to address our questions. First, to address the question of flexibility, we will examine only the first epoch of transfer trials. The results for the *same shape* group replicated our findings in experiment 1: a learning effect was clearly observed, with a significant slowing of RT during *between-group* trials compared to *within-group* trials in both the training and transfer (1^{st}-epoch) sessions (1,454 ms vs. 1,526 ms), $t(18) = 3.46$, $p < .003$, $d = .79$. In agreement, accuracy was also slightly, but significantly, worse in the *between-group* trials (97.9%) than on *within-group* trials (99.0%), $t(18) = 2.53$, $p = .02$, $d = .58$. On the other hand, although the *transformed shape* group showed significant *between-* vs. *within-group* slowing in the training phase, the transfer session did not reveal any significant learning effect (1,553 ms in both conditions), $t(18) < 1$; there was also no effect on accuracy (98.1% for *within-group* vs. 98.0% for *between-groups* trials), $t(18) < 1$. Indeed, an ANOVA on RT including grouping condition as a within-subjects factor, and group (*same shape* or *transformed shape*) showed a significant interaction, $F(1,36) = 4.79$, $p < .05$, $\eta^2 = .12$, such that between-group trials were slower than within-group trials, but only for the *same shape* group. This result suggests that the learning is quite specific to the orientation of the shape; simply inverting the shapes eliminates transfer of learning.

How durable are these representations? To answer this question, we compared the first and second epochs of transfer within the *same shape* group. In the second epoch of transfer, no *between-* vs. *within-group* effect was observed, $t(18) < 1$; there was a small but insignificant effect on accuracy such that *between-group* trials were slightly less accurate, as before, $t(18) = 1.15$, $p = .27$, $d = .26$. An ANOVA on RT revealed that the interaction between the factors of epoch and grouping condition approached significance, such that a grouping effect was observed in the first but not the second epochs, $F(1,18) = 3.80$, $p = .067$, $\eta^2 = .174$. This result suggests that this learning effect is eliminated, either by repeated exposure or by temporal delay, after around 120 trials of transfer, or 20 exposures to each shape pair.

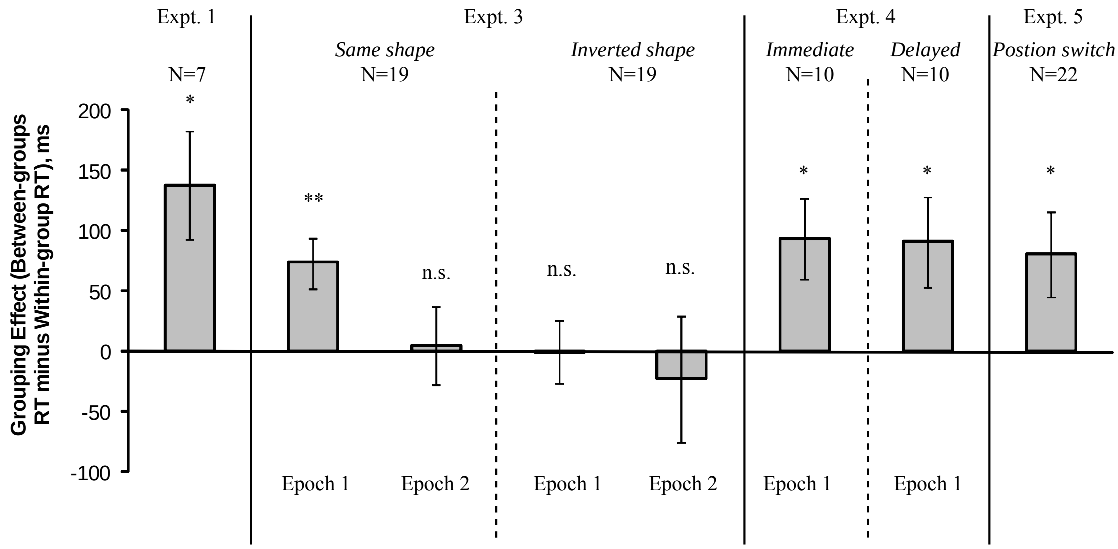

Figure 6. Summary of most important repetition discrimination transfer-phase results from all experiments (1, 3-5). Results plotted are mean RT differences between the *between-groups* and *within-group* conditions. A significant positive value implies grouping. Error bars are the standard errors of the difference. Significant results are indicated (* represents p<.05, ** represents p<.005).

Discussion

Experiment 3 reveals two interesting properties of associative grouping. First, the grouping measured here is specific to the conditions under which learning takes place. This implies that associative grouping is dependent on orientation-specific object recognition to operate. Inverting or otherwise mis-orienting familiar shapes, such as faces, is widely acknowledged to have a disruptive effect on recognition (e.g., Yin, 1969; Jolicoeur, 1985). In this experiment, we have shown an interesting twist on an inversion effect, in which interference that normally occurs due to learning is eliminated – an inversion *release* effect, as contrasted with inversion *interference* effects normally discussed in the literature. Experiment 5 delves into the question of flexibility in associative grouping from a slightly different perspective.

It was also found that, with longer transfer phases, the associative grouping effect dissipates. This may pose a challenge to the functional importance of associative grouping. If the dissipation of the effect is due to temporal decay, then the removal of the effect after only about 5-6 minutes of transfer testing would suggest that it is extremely fragile. However, if the effect was due to repeated experience of the shapes in an unpaired context, an ecological argument suggests that associative grouping may still play an important role in vision. As previously discussed, statistically associated features are typically confounded with grouping cues in the natural world. If the utility of associative grouping is to resolve ambiguity that occurs relatively rarely, then these associations should occur primarily in (relatively rare) occasions of accidental viewpoints and unusual lighting conditions. If the cues to grouping have disappeared, then an adaptive system that we are arguing for here should recognize that evidence supporting the grouping of these items has been diminished. In fact, if cues instead imply that the grouping structure was incidental, an adaptive system should abandon its commitment to the learned representation.

Such an adaptive system should show interference from evidence that suggests that groups are no longer relevant (the removal of grouping cues). Experiment 3 demonstrated dissipation of the grouping effect, but the reduction of the effect over time could also be due to simple decay, since the 2nd epoch of transfer was necessarily delayed. The next experiment takes up the question of whether the dissipation of associative grouping is due to temporal decay, or repeated exposure to ungrouped shapes, by introducing a fixed delay between training and the 1st epoch of transfer. If the adaptive system is responsible for the observed dissipation, then the delayed group should show the same effect in the 1st epoch that was observed in a non-delayed group.

Experiment 4: Dissipation of associative grouping: Decay or interference?

Experiment 4 was conducted to illuminate the roles of decay and interference in the elimination of the associative grouping effect observed in experiment 3's second epoch of transfer. The factor of temporal delay between training and the second epoch of transfer, and the factor of interference (more experience with ungrouped items between the training and second epoch) were confounded during experiment 3. Is the elimination of learning due to this experience, which might be expected to undo the effects of grouping, or was it due to simple temporal decay of the acquired associations? To answer this question, we tested two groups of subjects, the *immediate* and *delayed* groups. The *immediate* group experienced no more than normal delay between the training and transfer stages (the minimal time dedicated to setting up the experiment and giving instructions). On the other hand, the *delayed* group experienced an enforced ten-minute delay between training and transfer. This duration was chosen because it was minutes longer than the maximum amount of time that any subject in experiment 3 spent completing the first epoch of transfer.

<u>Methods</u>

Except where noted, the design and procedure of this experiment was identical to those applied to the *same shape* group of experiment 3.

Participants. 20 unique participants from the same population completed experiment 3, with 10 participants randomly assigned to each of the two groups.

Stimuli. We employed the original 24 shapes used in experiment 1, to ensure that the elimination of the learning was not specific to the newly created shapes.

Task and procedure. For the *immediate* group, the procedure was very similar to the *same shape* group of experiment 3. However, in this and all future experiments, the repetition discrimination task required pressing a button to indicate whether the repetition was light or dark, just as in the training stage of experiment 2B.

Other than this modification, the procedure for the *immediate* group was identical to experiment 3's *same shape* condition: 240 training trials were completed, followed as quickly as possible by 240 transfer trials. All trials were binned into 40-trial blocks.

For the *delayed* group, procedures were identical to those for the *immediate* condition, except that the conclusion of the training session triggered a 10-minute timer. At the end of 10 minutes, the experimenter set up the transfer phase, and the experiment proceeded as before.

Results

Training phase. Training phase results replicated experiments 1-3. A mixed-factor ANOVA on RT with group assignment as a between-subjects factor and grouping condition (*within-group* vs. *between-groups*) as a repeated measure factor showed no interaction and no main effect of grouping (both $F < 1$). There was a strong effect of grouping condition, $F(1,18) = 73.8$, $p < .001$, $d = 1.88$, such that responses to *between-group* trials ($M = 3{,}284$ ms) were slower than *within-group* trials ($M = 2{,}650$ ms), as expected.

Transfer phase. The *immediate* group's first epoch of transfer was examined to verify that the delay time of 10 minutes for the *delayed group* was appropriate. No subject took longer than 6 minutes, total, to finish the first epoch of transfer. Average duration of the first transfer stage was 5 min, 7s. Thus, the *delayed* group began their first epoch of transfer well after the maximum elapsed time between epoch 1 and epoch 2.

The results of experiment 4 showed that both the *immediate* and *delayed* groups expressed the group learning effect in the first epoch of transfer. The immediate group took on average 1,495 ms during within-group trials, while they took 1,589 ms on between-groups trials, $t(9) = 2.83$, $p = .02$, $d = .57$. This replicates the results of the previous two experiments. Replicating experiment 2, subjects showed a reduced and insignificant effect in the second epoch of transfer (1,486 ms in within-group trials, 1,511 ms in between-group trials; $t < 1$). Thus, the modified task had no influence on the qualitative pattern of results. The delayed group, who completed the experiment after a ten minute delay, also showed significant learning in the first epoch of transfer (1,654 ms vs. 1,746 ms), $t(9)=2.43$, $p = .038$, $d = .77$. Results for the delayed group in the second epoch trended toward faster responses in between-group than within-group trials, $t(9) = -2.11$, $p = .064$, $d = -.67$. Results for the first epoch of transfer was comparable across the two groups, with no interaction between the within-subject grouping factor and the between-groups factor of delay, $F<1$.

<u>Discussion</u>

The outcome of experiment 4 proves that decay is not the determining factor of the dissipation of associative grouping, which instead probably arises mostly from repeated experience of the objects in an ungrouped formation. Since statistical association is often confounded with grouping cues, associative grouping may play an important role in vision, even if the statistical associations that determine its formation are temporally remote from time of expression. The mechanism behind associative grouping should be expected to update the probability that two items belong together, even after it has learned to associate two shapes together. If this were not the case, then it would rigidly assume that two elements are unitized even with a great deal of experience to the contrary. In these experiments, it is worth noting that persistence over 20 transfer trials is remarkable, given that learning included only 40 exposures under explicit grouping conditions.

Experiment 5: Flexibility to transposition of grouped shapes

Experiment 3 demonstrated that associative grouping is not flexible to at least one transformation of the shapes (inversion). This suggests the possibility that this learning might reflect a sort of rigid "template formation," in which an exact shape, consisting of the two constituent shapes, or the negative space between the shapes, is acquired. This interpretation does not jibe with the perceptual grouping account that we have presented here, which would intuitively predict more flexibility of transfer than a simple template theory. However, there is reason to believe that the inversion manipulation would reduce the transfer of learning even under a perceptual grouping account of this phenomenon given the dependence of shape recognition on orientation. Therefore, we examined further the flexibility of associative grouping in experiment 4.

In experiment 5, we exploit the fact that in prior experiments participants always experienced the shape pairs as occurring in the same order. In other words, a row composed of shapes A, B, C, and D would always present group associates AB and CD in that order, and never BA or DC, during training. We propose that a *perceptual grouping account* predicts flexibility to transformations of order. A perceptual grouping account would propose that the grouping occurs by virtue of the assignment of "token" identities to the shapes, and the abstract token identities are associated by the learning process. Therefore, the ordering of shapes should be irrelevant as long as the tokens are recoverable. By this account, learning was not exhibited when the shapes were inverted (experiment 3) due to an impairment of token formation. On the other hand, a *strict template* view of these results might suggest rigidity to such a transformation. That is, it is possible that what is learned is the joint shape, or joint shape characteristics such as the negative space between the shapes, or the joint outline. Thus, the template is activated whenever the two shapes co-occur in a particular formation, and performance is altered based on the activation of this template. By this account, any manipulation that affects the overall joint shape of the pair should reduce the effects of learning, including inverting or transposing the shapes.

In this experiment, we tested participants under conditions that closely mimicked those of the *immediate* group of experiment 4, employing that group as a point of comparison. All participants in experiment 5 were trained as in experiment 4. In the transfer stage, however, all groups were reversed in position, such that any trained shape combination AB was seen in the transfer phase as BA. While a lack of transfer to such conditions would not rule out the *perceptual grouping hypothesis*, the existence of transfer would strongly bolster the case for perceptual grouping compared with the *template hypothesis*.

Methods

Participants. 22 unique participants from the same population completed experiment 5.

Design. All details of experiment 5 were identical to those of the *immediate* group of experiment 4, except for two modifications. First, in the transfer stage, each row's items were reversed in group position. That is, if the training exposed subjects to rows composed of A, B, C, and D (ABCDAB…ABC), with AB and CD grouped together, the transfer session trials with these shapes reversed the positions of AB and CD (e.g., BADCBADCBAD). The second modification was to eliminate the second epoch of transfer in order to shorten the length of the experiment.

Results

Training phase. Performance during the training phase was similar to prior experiments. There was no significant effect of grouping condition on accuracy (98% in both conditions, $t < 1$). There was a strong grouping effect on RT, with slower responses on *between-groups* trials than *within-group* trials (3,628 ms vs. 2,870 ms), $t(21) = 9.09$, $p < .001$, $d = 1.94$.

Transfer phase. Results of the transfer phase provide convincing evidence for the *perceptual grouping hypothesis*: participants showed a significant grouping effect in the transfer stage, such that *within-group* trials were faster than *between-group* trials despite the position reversal experienced in the transfer stage (1,653 ms vs. 1,733 ms), $t(21) = 2.28$, $p=.03$, $d = .49$. In addition, accuracy analysis showed a borderline significant result, with slightly less accurate responses in *between-groups* than *within-group* trials (98.9% vs. 98.0%), $t(22) = 2.05$, $p = .053$, $d = .44$.

An interaction test between experiment 4's *immediate* group transfer phase results and experiment 5's transfer phase results showed no significant interaction ($F < 1$), suggesting that the grouping effect was comparable regardless of whether element position was changed or the same as in training.

Discussion

In contrast to the inversion manipulation of experiment 3, constituent position reversal resulted in preserved associative grouping. These results are evidence against a strict template hypothesis, demonstrating flexibility in the face of one transformation that would be expected to violate the confines of a template that incorporated both group shapes.

General Discussion

These experiments provide further support for the notion that experience alters perceptual grouping, generally, and give the most direct evidence to date that associative learning can induce perceptual grouping. Despite the short duration of training, and the irrelevancy of the grouping dimension, exposure to explicitly segmented pairs was sufficient to induce *associative grouping* effects. This learning effect manifests in slower reaction times to locating color repetitions that crossed associated-shape grouping boundaries compared to those contained within associated-shape grouping boundaries, implying that it was not imposed artificially by the observers. It also manifests as a spatial distortion effect that matches the spatial distortions observed with grouping by color or shape similarity.

Associative grouping is subject to interference: repeated observation of the constituent shapes led to an elimination of the associative grouping effect in experiment 3. However, experiment 4 demonstrates that this elimination is not due to temporal decay, and we believe that this is not a source of much doubt concerning the importance of associative grouping in shaping visual processing. The primary role of associative grouping may be to resolve ambiguity that arise from accidents of viewpoint or lighting that leave the structure of a scene in doubt. Although such situations may occur quite often, we suggest that they are rare compared to those situations in which a potent grouping cue coincides with statistically associated features. Thus, such associations may be frequently reinforced between episodes of such ambiguity. The elimination of the effect after repeated exposure to ungrouped items reflects the logical operation of such a flexible system.

Associative grouping is inflexible to inversion of individual objects, but flexible to within-group position reversals. In this respect, it also bears a relationship to Peterson and colleagues' findings that shape recognition influences figure-ground segmentation (Peterson, Harvey, & Weidenbacher, 1991; Peterson & Gibson, 1994); they found that inverting the shapes, and thus interfering with shape recognition processes, also eliminated their effect. This finding also hints that known shape recognition mechanisms, with their sensitivity to orientation (Jolicoeur, 1985), may be involved in associative grouping mechanisms, as opposed to a specialized or distinct shape recognition route.

On the other hand, the flexibility to left-right position reversal observed in experiment 5 implies that the relationships between constituent features in associative grouping are somewhat abstract and independent of position. This is an important fact, because it reduces the probability that our results are due to visual templates formed by the observer. A strict template formed from, say, repeatedly searching for two objects together, should encompass the shapes of both objects in the experienced orientation.

In the introduction, we called attention to the fact that recognition memory is the standard dependent variable in most visual statistical learning (VSL) studies. We claim that recognition memory does not necessarily reflect perceptual grouping, per se, and that perceptual grouping may not necessarily result in recognition, per se. Indeed, in further studies of these effects (Vickery & Jiang, in preparation), we have found that training methods producing extremely high recognition memory rates for shape pairs can lead to no evidence of perceptual grouping (in terms of the speed difference in repetition discrimination). On the other hand, the same basic training method used in every experiment of this paper leads to a strong repetition discrimination transfer effect, but very poor recognition memory of grouped versus ungrouped pairs. Participants trained in the procedures used in this paper produced recognition rates for grouped vs. ungrouped pairs that did not differ significantly from chance. This enhances the need for further study to determine the nature of representations formed from VSL, by employing a diversity of dependant measures and comparing them to the sorts of trained grouping effects observed in this study.

These results beg a number of other interesting questions. For instance, does the strength of associative grouping depend on the probability that the two shapes are bound together? This question should be asked in future studies of associative grouping. From these results it cannot be determined whether associative grouping would ever occur if the constituent shapes appeared grouped with other items, much less if the strength of the grouping effects would vary depending on the probability that they should be grouped.

Our learning effect bears some commonalities to other priming effects in visual cognition, in particular the phenomenon of contextual cueing (Chun & Jiang, 1998). Contextual cueing refers to the speeded visual searches that occur when distracter and target positions recur over the course of many searches, relative to configurations that do not recur. Like contextual cueing, our results may be due to changes in the way that attention is distributed. Also similar to contextual cueing, associative grouping may be an implicit memory effect: in a separate set of studies, we have found weak or non-existent recognition memory for associative groups (Vickery & Jiang, in preparation). In contrast to contextual cueing, associative grouping implies perceptual grouping between shapes, and occurs despite the fact that it confers no obvious advantage in either the training or transfer task.

Even Wertheimer (1923) recognized the possibility that learning could be important to grouping. In his famous work on perceptual grouping, Wertheimer proposed the “factor of past experience.” He argued that experience might shape perceptual grouping, but he failed to produce a compelling demonstration of this, similar to those provided for proximity and similarity. In fact, he produced a salient counterexample, placing letters in configurations that led other grouping cues to dominate, which showed that experience could not overcome the other proposed laws of grouping. The view that experience is relatively unimportant to perceptual grouping is finally starting to be challenged. In this study, we have provided further empirical evidence for the factor of experience in perceptual grouping, by demonstrating an associative aspect. We do not contend that this factor has been shown to dominate other grouping factors. However, we propose that the factor of associative experience is to provide guidance to the visual system when other grouping cues fail to produce a strong, unambiguous grouping.

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