



DIPLOMARBEIT

Transfer of information between the local and the global
processing level in categorization and
identification tasks by pigeons

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Abstract

This study investigated if pigeons, like humans, are able to transfer information between the local and the global processing level and if category structure or picture size have an influence on the chosen level. In the first experiment eighteen pigeons were successively trained on two tasks in a two-alternative forced-choice procedure with either intact (global and local level intact), scrambled (only local level intact) or blurred (only global level intact) stimuli. In one task they had to learn pictures by rote (Identification task) while in the other they could use a perceptual rule (tree/nontree pictures, Categorization task). After training they were confronted with the two untrained stimulus types, with pictures that were scrambled or blurred to higher or lower degrees, with grayscale pictures, with pictures that were both blurred and scrambled, and (in the Categorization task) with novel tree and nontree pictures in all presentation modes. A second experiment was run with 18 novel pigeons that were subjected to the same trainings and tests but with the pictures being a quarter of the area of the picture size of the ones shown in the first experiment and an additional test to see if they were able to transfer to the original picture size. The results showed that intact local information was essential for both memorizing individual stimuli and abstracting a perceptual rule with a "transfer barrier" obviously impeding generalization from and to pictures where local information was impaired (i.e., the blurred ones). Category structure and picture size had no effect on the pigeons' choice of processing level. Thus, their "local precedence" had to be due to other factors with some likely candidates being viewing distance, availability of local/global features, and salience of individual stimulus properties. In particular, color cues were found to be important. In summary, the results failed to show evidence of pigeons being able to transfer between the local and the global processing level.

Zusammenfassung

Diese Studie befasste sich mit der Frage, ob Tauben wie Menschen, zu einem Informationstransfer zwischen der lokalen und der globalen Verarbeitungsebene in der Lage sind, und ob für die Tiere die Kategorie und die Größe der Bilder die Wahl der Informationsebene beeinflusste. Im ersten Experiment wurden 18 Tauben mit einer „two-alternative forced choice“ Prozedur trainiert, in der sie entweder mit intakten (lokale und globale Information intakt), zerstückelten (nur lokale Information intakt) oder verschwommenen (nur globale Information intakt) Stimuli konfrontiert wurden. Der Einfluss der Kategorie wurde in zwei Aufgaben untersucht, wobei eine der Aufgaben das Auswendiglernen der Bilder erforderte (Identifikationsaufgabe), während die andere durch die Anwendung einer perzeptuellen Regel gelöst werden konnte (Baum/Nicht-Baum Bilder (Kategorisierungsaufgabe)). Im Zuge der nachfolgenden Tests wurden die Tauben mit den beiden zuvor nicht trainierten Reiztypen konfrontiert, mit Bildern mit unterschiedlichen Modifikationsgraden in Bezug auf Zerstückelung bzw. Verschwommenheit, mit Bildern in Graustufen, mit Stimuli die sowohl verschwommen als auch zerstückelt waren, sowie (in der Kategorisierungsaufgabe) mit neuen Baum- und Nicht-Baum-Bildern in allen drei Präsentationsmodi. Im zweiten Experiment durchliefen 18 weitere Tauben dieselben Trainings und Tests wie die Tauben im ersten Experiment, allerdings mit dem Unterschied, dass die Bilder um ein Viertel verkleinert waren. Des Weiteren wurde ein zusätzlicher Test durchgeführt, in dem die Vögel auf Transfer zu den größeren Bildern getestet wurden.

Beide Experimente ergaben, dass intakte lokale Information sowohl für das Erinnern einzelner Reize als auch für die Abstraktion einer perzeptuellen Regel wichtig war, wobei eine "Transfer-Barriere" offenbar die Generalisation von und zu Bildern mit zerstörter lokaler Information (d.h., verschwommene Bilder), behinderte. Kategoriestructur und Bildgröße hatten keinen Effekt auf die Wahl der Verarbeitungsebene. Daher musste ihre Bevorzugung der lokalen Ebene auf andere Faktoren zurückzuführen sein, zu, Beispiel der Betrachtungsabstand, die Verfügbarkeit von lokalen/globalen Merkmalen und die Augenfälligkeit einzelner Stimulusmerkmale. Insbesondere Farbmerkmale waren offenbar von Bedeutung. Insgesamt erbrachten die Ergebnisse keine Hinweise darauf, dass Tauben Information zwischen der lokalen und der globalen Verarbeitungsebene transferieren können.

Introduction

When you walk through an art museum you can look at the paintings in two different ways. You can perceive the pictures either as a whole or you can see them as consisting of different parts. For example you can look at a portrait and see the whole face or you can concentrate on the nose, eyes or other parts. These two levels of viewing are called the global and the local level. The global level has two definitions (see Cook, 2001). First, it is the overall stimulus configuration (i.e., the overall shape and the spatial relationships among parts); second it means the physical characteristics of the whole stimulus (e.g., overall brightness, texture, color distribution). In this study the global level refers to the overall stimulus configuration. The local level, as defined by Cook (2001), is the part-based description of information and the spatially limited physical characteristics, for example the details of a stimulus.

It seems that humans often show a global precedence effect when they are simultaneously confronted with both levels (Navon, 1977; Goto et al., 2004), but they can also transfer from one level to the other when information from one level is degraded (Schwaninger et al., 2002). Studies with baboons and chimpanzees showed that these animals perform better at the local level than at the global level (Fagot & Tomonaga, 1999; Fagot et al., 2001). But primates aren't the only subjects scientists study when they do research on the mechanisms underlying visual processing. Cerella (1980), for example, showed that pigeons recognized line drawings by focusing on local details rather than by viewing the overall configuration. This outcome was also found in other studies (Cavoto & Cook, 2001; Gibson et al., 2005), and it was therefore suggested that the local level is fundamental for pigeons' picture perception and that the global level is unimportant. This effect is also called the "local precedence effect" (Cook et al., 1992; Cavoto & Cook, 2001; Gibson et al., 2005). However, it has been shown that pigeons are able to attend also to spatial arrangements of object components (Kirkpatrick-Steger et al., 1996; Kirkpatrick-Steger et al., 1998). Other studies stated that the animals can selectively focus on either global or local information and that the type of stimuli (e.g., cartoons or photographs) and the context are important for the chosen level (Aust & Huber, 2010; Fremouw et al., 1998; Matsukawa et al., 2004; Watanabe,

2001; Watanabe, 2011; Watanabe & Ito, 1991). Furthermore, the birds can shift attention between these two levels of visual analysis (Fremouw et al., 2002; Lazareva et al., 2006). One study by Goto et al. (2004) even showed that pigeons recognized the global level faster than the local level.

One method to test on which level a subject is focusing is the use of hierarchically structured stimuli (Cavoto & Cook, 2001; Fremouw et al., 1998; Fremouw et al., 2002, Navon, 1977;), in which one big letter (global level) is formed by small individual letters (local level). Another method, which was also used in the present study, is to use scrambled and blurred stimuli (Goto et al., 2011; Kirkpatrick-Steger et al., 1998; Matsukawa et al., 2004; Schwaninger et al., 2002; Watanabe, 2001). The idea behind this technique is that in blurred pictures local information is destroyed and by scrambling (meaning that the picture is divided into smaller parts and the parts are then randomly rearranged) global information is destroyed. Studies using this method showed that pigeons are able to recognize scrambled pictures but that there is a decrement in performance with increasing scramble degrees (Aust & Huber, 2001; Matsukawa et al., 2004). However, it is not always the case that pigeons recognize scrambled stimuli as other studies have shown (Watanabe, 2001; Watanabe & Ito, 1991; Lazareva et al., 2006). Therefore it seems that global information is important for them, too.

Which processing level pigeons choose seems to depend on many factors. It was found that, for example, viewing distance, picture size, configural organization, feature salience, the type of stimuli (e.g., cartoons or photographs), the context in which the stimuli were presented and the duration of the presentation of a stimulus may play a role in the choice (Cavoto & Cook, 2001; Goto et al., 2004; Matsukawa et al., 2004; Watanabe, 2001; Watanabe & Ito, 1991). Furthermore, Fremouw and colleagues (1998) showed that pigeons preferred the level which was frequently presented. This means that when local displays were more common they preferred the local level, and when global displays were more common they preferred the global level.

Yet another factor which may be important in pigeons' choice of processing level could be the category structure, but so far this has not been studied. We can differentiate between categories where the subject has to associate every single stimulus with the category to which it belongs (i.e., by learning it by rote), and categories where correct classification depends on the subject finding the category-specific features of the stimuli

that qualify them as class members (i.e., abstraction of a perceptual rule). By learning the category rule the subject is able to recognize also novel instances as members of the learnt class. In this study the first type of task is called "Identification task" and the second is called "Categorization task". Categorizing objects by a rule has the benefit that you don't have to memorize all members of a class, i.e., it is more economical in terms of storage capacities. But a disadvantage is that information about the individual stimuli is lost. Due to the different advantages both processes have, Cook and Smith (2006) suggested that animals use both. Studies with pigeons showed that they indeed have the ability to solve Identification tasks (Chase & Heinemann, 2001; Cook et al., 2005; Fagot & Cook, 2006) and Categorization tasks (Aust & Huber, 2001; Huber et al., 2000; Herrnstein & Loveland, 1964; Herrnstein & de Villiers, 1980; Watanabe et al., 1995).

In summary, it has been shown that pigeons are able to use global and local information and can shift between these two processing levels and that they can solve Identification as well as Categorization tasks. But what hasn't been investigated so far is the interaction of these two aspects and that is why this study was conducted. The aims of the present experiments were: To find out

- 1) ... if the category structure (Identification versus Categorization task) has an influence on the choice of the processing level. In particular, the hypothesis was explored that pigeons may depend more strongly on local information in Identification tasks because here the birds may memorize specific details of a stimulus, but may rather rely on global information in Categorization tasks in which they have to find a category-defining target (e.g., a tree figure).

- 2) ...if pigeons are able to make a transfer from the local to the global processing level and vice versa. Regarding humans, Schwaninger et al., (2002) showed that, indeed, participants were able to make such a transfer when confronted with human faces.

- 3) ... if it's possible to reduce pigeons' preference for local information by reducing stimulus size and push them towards using global rather than local information.

To test this, my study was divided into two experiments: Experiment 1 investigated the first two questions, whereas Experiment 2 was concerned with the third. Experiment 1 was part of a comparative study (Aust & Braunöder, submitted) in which performances of both humans and pigeons were investigated. The study was conducted also with humans to see if their ability to transfer from one level to the other would still be present

when they are confronted with different stimuli and with another method than used by Schwaninger: Instead of pictures of human faces Aust and Braunöder used photographs of natural scenes and artificial stimuli (like computer-generated patterns; see methods section), and the subjects were trained not in a priming paradigm but with a two-alternatives forced-choice procedure. My diploma thesis includes, however, only the pigeon part of the experiment. In Experiment 2, which constitutes the second part of my diploma thesis, the question was investigated if the stimuli size has an effect on the birds' choice of processing level and it was done only with pigeons.

In both experiments one subject group was trained with intact pictures (i.e., the animals could rely on both global and local information), another with scrambled pictures (i.e., global information was degraded, local information was intact) and the third with blurred pictures (i.e., local information was degraded, global information was intact). After training, it was tested if the animals were able to transfer to the other two (previously untrained) presentation modes (Test 1). Test 2 was conducted to find out if a higher or lower degree of scrambling and blurring would have a different effect on stimulus recognition. Test 3 investigated the importance of color for recognition. So the birds were confronted with grayscale versions of all pictures in all presentation modes. In Test 4 the subjects were confronted with stimuli which were both blurred and scrambled. This has the effect that both levels, global and local, are destroyed and maybe there would be an additive detrimental effect of the two manipulations so that the animals would not be able to recognize the stimuli anymore. Because of pigeons' great capacities to memorize pictures by rote (Vaughan & Greene, 1984; von Fersen & Delius, 1989) Test 5 was conducted to make sure that the birds indeed solved the Categorization task by using the rule. To this end they were confronted with novel tree and nontree pictures in all presentation modes. Experiment 2 was the same as Experiment 1 with the exception that the stimuli were half the size of the pictures of the first experiment. Furthermore, the animals in Experiment 2 had to do an additional test (Test 6), in which they were confronted with pictures of original size (i.e., the same as in Experiment 1) in all presentation modes.

Experiment 1

1. Introduction

Studies showed that pigeons are able to use global and local information and shift between these two processing levels and they can solve Identification as well as Categorization tasks (Aust & Huber, 2001; Cavoto & Cook, 2001; Cerella, 1980; Fagot & Cook, 2006; Fremouw et al., 1998; Fremouw et al., 2002; Matsukawa et al., 2004; Troje et al., 1999; Watanabe et al., 1995). The first experiment was conducted to investigate if the category structure would have an influence on pigeons' choice of processing level and if they would be able to transfer information between processing levels as humans can do (Schwaninger et al., 2002).

2. Methods

2.1 Subjects

For the experiment 18 pigeons of mixed sex were used as subjects. Fifteen of them were homing pigeons (*Columbia livia domestica*) and three were of the local Austrian race "Strasser". The animals were group-housed in five aviaries at the Biocenter of the University of Vienna. During the experiment the birds received food only in the Skinner-box when they were doing their experimental sessions, but water and grit were always available in the aviaries.

2.2 Apparatus

The pigeons were trained in six indoor Skinner-boxes. All birds were used to working in any of these boxes and were arbitrarily trained in any of them each day, depending on the immediate availability of the individual boxes (which were all run in parallel). Each box had a size of 50 x 30 x 40 cm. The stimuli were presented on a 15" XGA Color TFT-LCD monitor (resolution 1024 x 768 px) which was mounted behind an infrared touchframe (model D87587-001, by ELO, Menlo Park, CA) on the front side of the box. When the animals pecked on the correct picture they received food. The feeder was driven by an electric motor that lifted a piston with a depression on top through a food reservoir. Then the piston was lifted through a hole in the bottom of the testing chamber

and the food became available for the pigeons below the touch screen. Thereafter, the piston moved back into its "waiting position" where it could no longer be reached by the birds. When the piston was lifted up its top was illuminated by a white LED. Each Skinner-box was connected to a PC, equipped with electronics to run the presentation program and to control the feeder as well as with a software package (PigeonLab, M. Steurer) to handle data acquisition and device control. More technical details can be found in Steurer et al. (2012).

2.3 Stimuli and procedure

A two-alternative forced-choice procedure (2 AFC) was used, which means that in every trial one positive (S+) and one negative stimulus (S-) were simultaneously shown on the black background of the screen. The stimuli were located on the screen at about pigeon eye level, one appearing somewhat left of the middle of the screen and the other appearing somewhat right.. In every trial the positions of the wrong (S-) and the correct stimulus (S+) were randomly chosen by the program and picture pairings were randomly varied from session to session.

When the birds pecked on the correct stimulus, both stimuli disappeared and the subjects heard a 600 Hz sound for 50 ms. During the following intertrial interval (ITI) of 4 sec the screen remained black and the piston of the feeder became available to the birds for 3 sec. Then the next trial followed. But when they chose the incorrect stimulus the screen turned red for 3 sec and a 200 Hz sound was produced for 50 ms. Then the same two pictures as before were shown in the same positions. This correction procedure was repeated until the subjects made the correct choice whereupon they received food and the trial was terminated. This procedure was identical for training and test phases. The animals had to do sessions from Monday to Friday and the number of daily session varied, depending on their motivation.

The original pictures were taken from royalty-free internet databases and adapted in Photoshop CS2. The stimuli that were eventually presented had a size of 112 x 112 pixels (resolution: 96 dpi), resulting in a size of 2.4 x 2.4 cm on the monitor.

2.3.1 Training

All subjects had to learn two tasks. In the Categorization task colored photographs showing trees were defined as positives and photographs without trees were defined as negatives. The Identification task was a rote learning task in which perceptually random pictures (for example, comic figures, textures, pieces of art or computer graphics) were arbitrarily defined as positives or negatives (Figure 1). Each task involved 20 positive and 20 negative stimuli and in every session all 40 pictures were shown, so that all sessions consisted of 20 trials (with each trial involving the presentation of one positive and one negative picture). In each of the two tasks, one group of three pigeons was trained with the original, intact (Int) pictures (Group Intact) so that the animals could use either local or global information or both. The second group of three pigeons (Group Scrambled) worked with the scrambled versions (Scr) of the pictures presented to Group Intact. This means that the original pictures were divided into 4 x 4 squares and the squares were randomly reassembled. As a consequence, fine details remained intact but the overall configuration was destroyed. Thus, the animals could use only local information. The pictures presented to the three pigeons of the third group (Group Blurred) were made by blurring the original pictures (Blur) with the Photoshop Gaussian filter with a radius of 5 pixels. This had the effect that overall configural cues (i.e., global information) remained intact, but fine details (i.e., local information) were widely destroyed (Figure 1).

Half the subjects (nine animals) were trained on the Categorization task first, and the other half were trained on the Identification task first. When the birds had accomplished the first task (Identification or Categorization Task) and all associated tests, they were trained and tested on the other task. By this, group sizes were increased ($n = 6$) and any potentially occurring order effects were counterbalanced. The animals started with the tests when their training performance fulfilled the learning criterion (see 2.4 Data analysis). The full sets of training and test stimuli are shown in the Appendix (3. Stimuli).

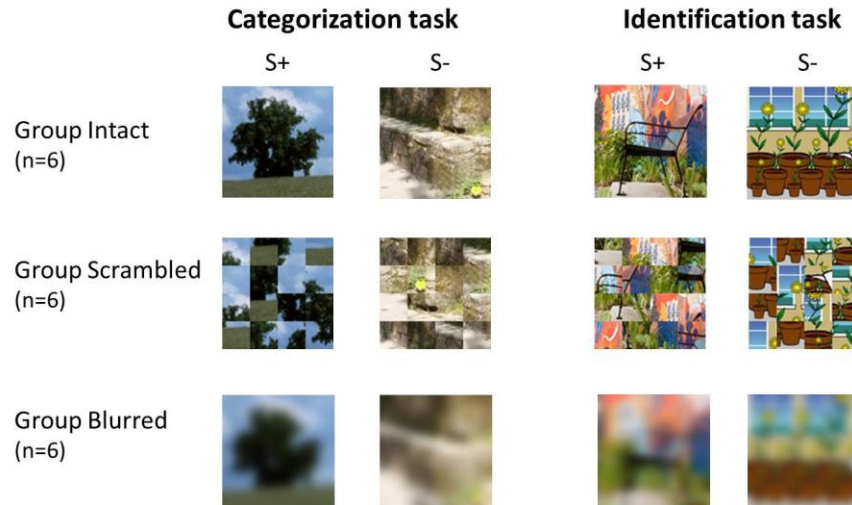


Figure 1: Examples of training stimuli shown to Groups Intact, Scrambled, and Blurred in the two tasks.

2.3.2 Test 1: Transfer to the other presentation modes

In the first test the pigeons were confronted with pictures shown in the two previously untrained presentation modes. For example, subjects of Group Intact were confronted with blurred and scrambled versions of their (intact) training pictures (Figure 2). In every session two training trials (i.e., four stimuli) were replaced with versions of the same pictures in the two presentation modes not presented in training. Thus, each test session consisted of 22 trials (18 training trials and four test trials). The whole test comprised a total of 10 test sessions with a total of 20 test trials of each of the two tested presentation types. The first trial in a test session was never a test trial and there were never two or more test trials in a row. This procedure was the same in all tests.

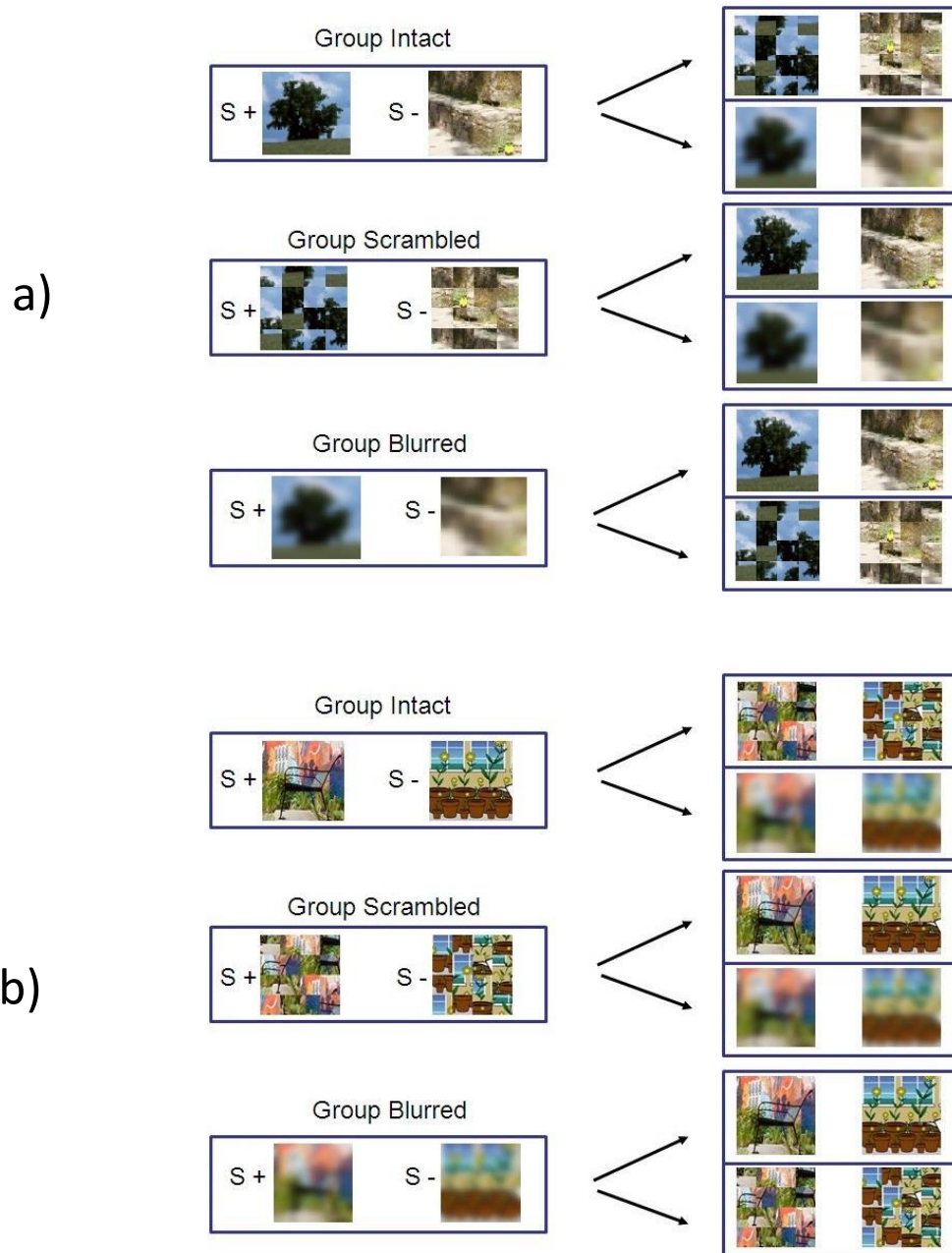
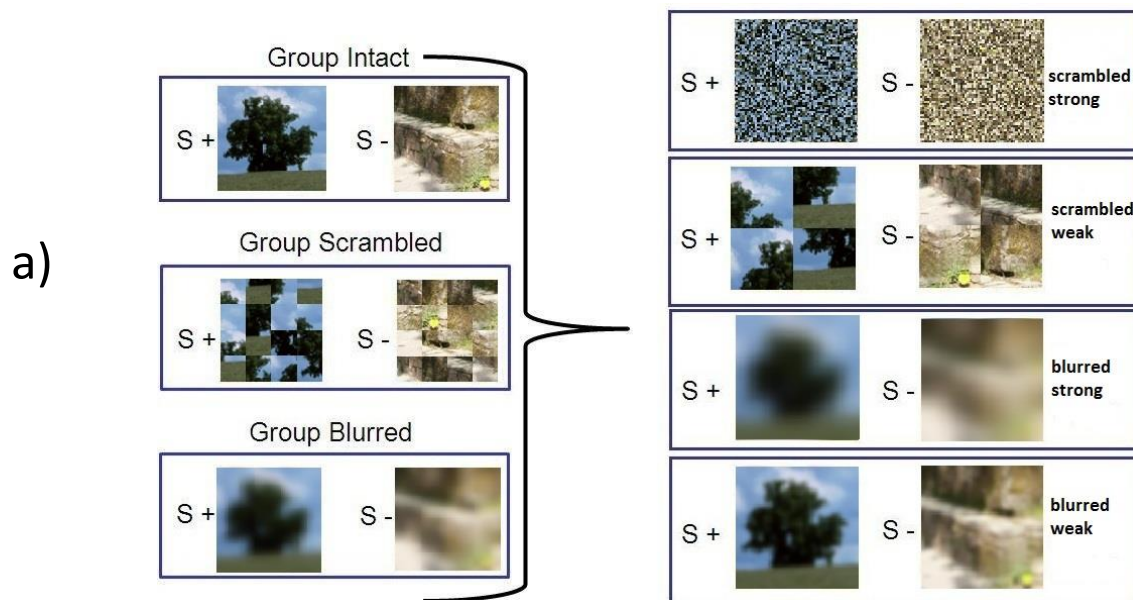


Figure 2: Examples of training (left) and test stimuli (right) of Test 1 shown for all groups and separately for the Categorization (a) and the Identification task (b). In test trials Groups Intact were confronted with blurred and scrambled pictures. Groups Scrambled were confronted with intact and blurred stimuli, and Groups Blurred saw intact and scrambled pictures.

2.3.3 Test 2: New scramble and blur degrees

The second test explored the impact of the degrees of scrambling and blurring on recognition as well as on the transfer from local to global information and vice versa. To this end the pigeons were confronted with pictures that were either more or less strongly scrambled (Scr strong or Scr weak) or blurred (Blur strong or Blur weak) than the original stimuli. The strongly blurred stimuli were made by applying the Gaussian filter with a radius of 8 pixels. For the weakly blurred pictures a radius of 2 pixels was used. The strongly scrambled pictures were made of 56 x 56 squares and the weakly scrambled ones consisted of 2 x 2 squares (Figure 3). In each test session two training trials (i.e. four pictures) were replaced with the strongly and weakly scrambled and blurred versions of these pictures. One test session thus consisted of 18 training trials and eight test trials, which means that there were 26 trials in a session. The whole test comprised a total of 10 test sessions and there were 20 test trials of each presentation type.



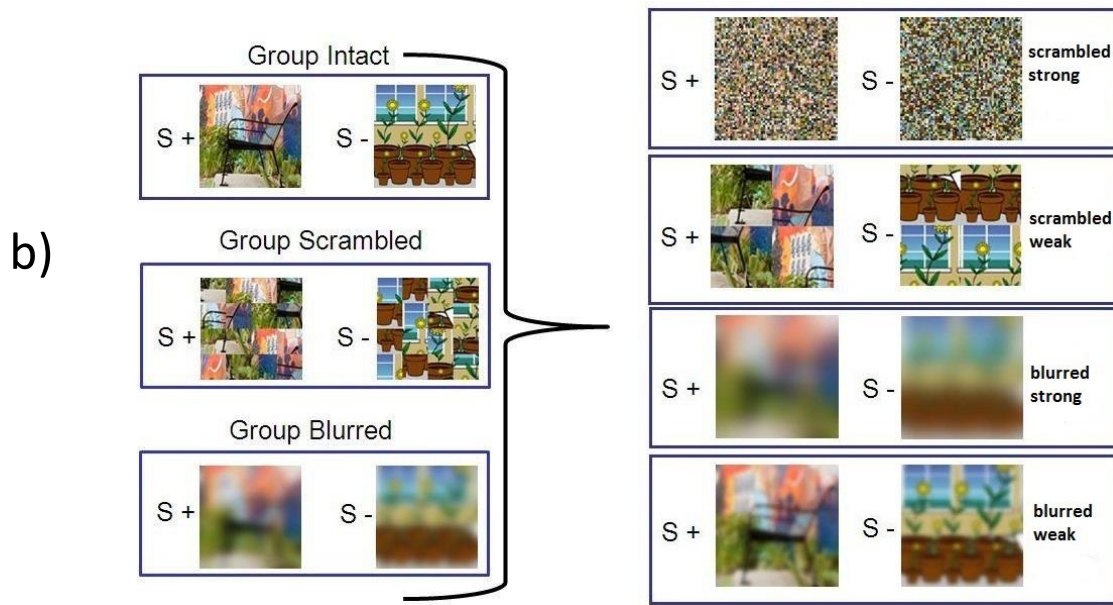


Figure 3: Examples of training (left) and transfer stimuli (right) of Test 2 shown for all three groups and separately for the Categorization (a) and the Identification task (b). All groups were confronted with strongly and weakly scrambled and blurred pictures.

2.3.4 Test 3: Grayscale versions of all three picture types

In order to see how important color was for the animals to recognize the stimuli the pigeons were confronted with grayscale versions of all three picture types (Int gray, Scr gray, Blur gray). In each test session two training trials (i.e., four stimuli) were replaced with grayscale versions of the respective stimuli (Figure 4). Each test session consisted of 24 trials, 18 training trials and six test trials. The whole test comprised a total of 10 test sessions and there were 20 test trials of each presentation type.

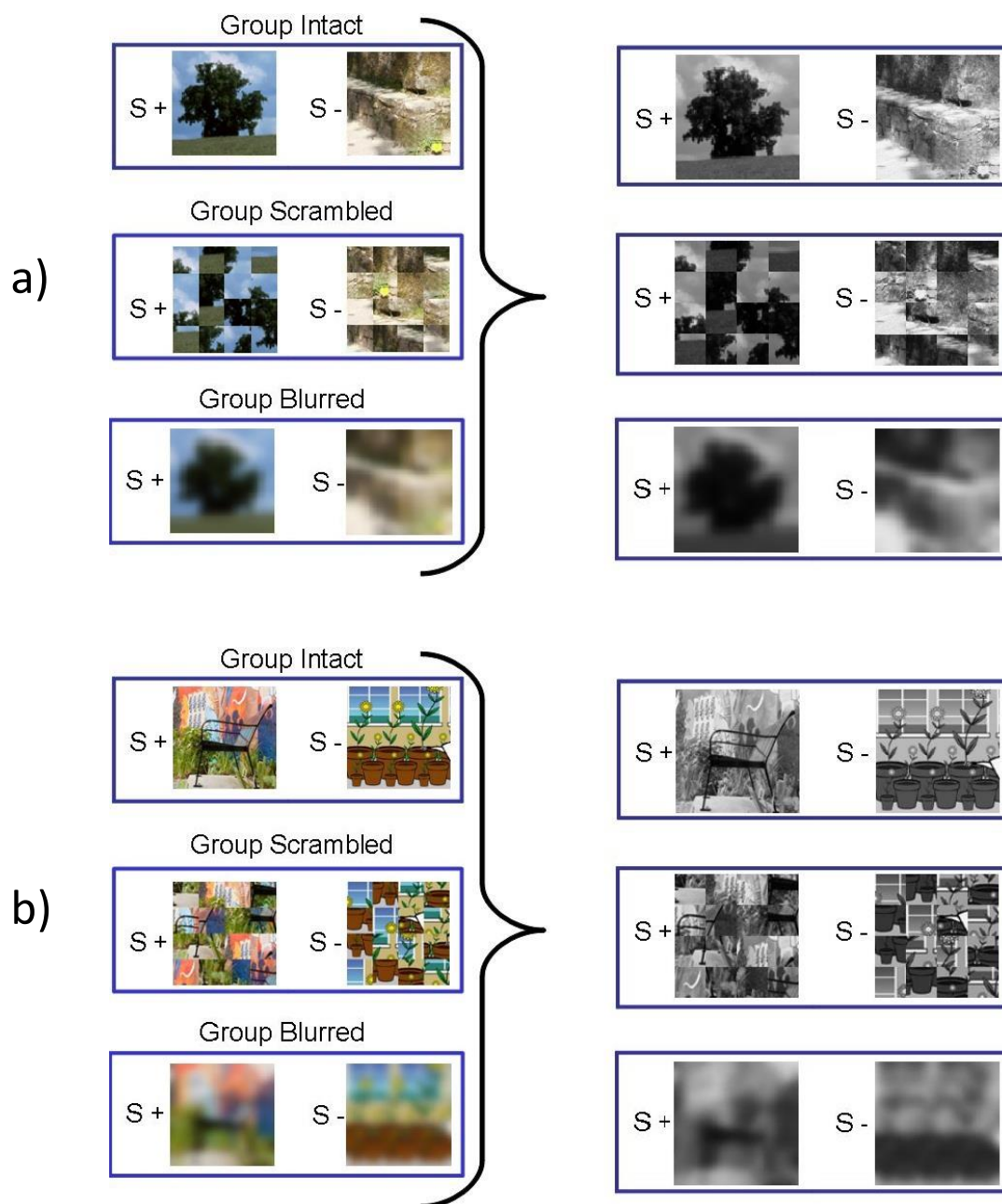
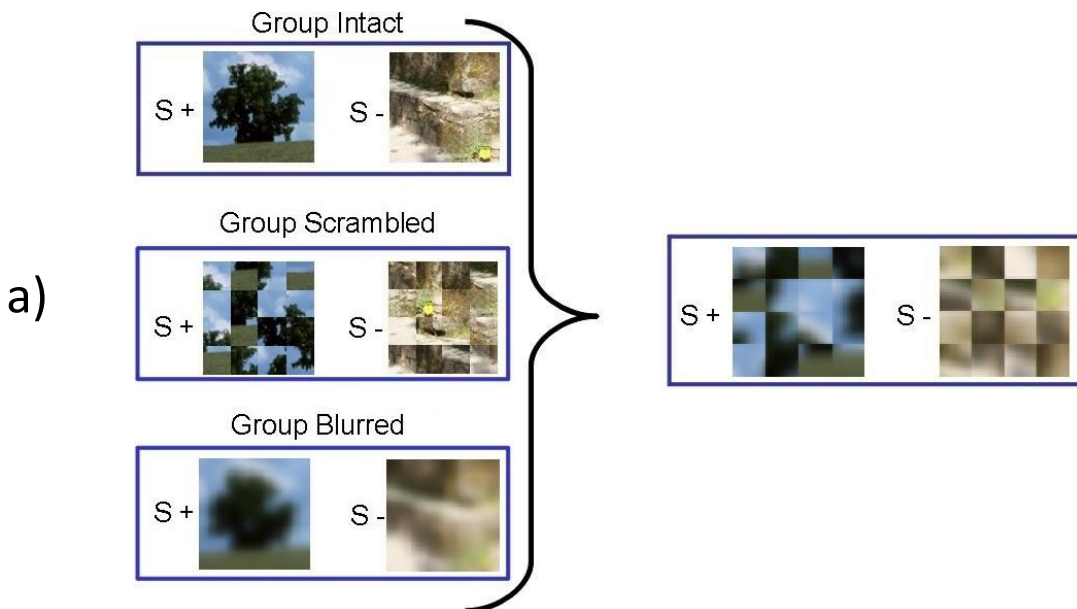


Figure 4: Examples of training (left) and transfer stimuli (right) of Test 3 shown for all three groups and separately for the Categorization (a) and the Identification task (b).

2.3.5 Test 4: Both blurred and scrambled pictures

In the fourth test the animals were confronted with pictures in which both local and global information was degraded. This test was done to find out if the effects of both manipulations would add up and its results should assist in further judging the relative importance of the two processing modes. Failure to recognize the test stimuli would confirm the general effectiveness of the two manipulations in removing all relevant local and global information. In turn, residual discrimination would be an indicator of the extent to which remnants of local and/or global information that were still present in the pictures could be used (such as tiny local features or overall color or brightness cues). To this end, the blurred training stimuli were additionally scrambled (Blur & Scr) (Figure 5). One test session had 20 trials (two test and 18 training trials). The whole test comprised a total of 10 test sessions and overall there were 20 test trials.



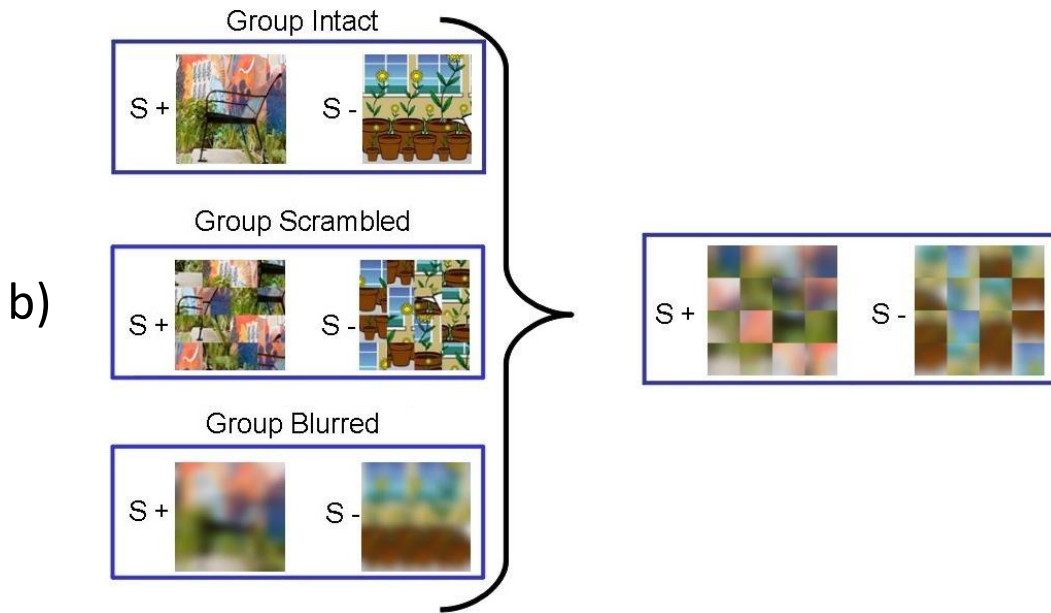


Figure 5: Examples of training (left) and transfer stimuli (right) of Test 4 shown for all three groups and separately for the Categorization (a) and the Identification task (b).

2.3.6 Test 5: Novel category instances

The last test was conducted only in the Categorization Task. There, the birds were confronted with new tree and nontree stimuli in all three presentation modes (Int nov, Scr nov, Blur nov; Figure 6). The test was done to see if the pigeons indeed learned the categorization rule or if they just learned by rote on a pixel-by-pixel basis. Other than in the previous tests no training trials were replaced but six test trials were added. So there were 26 trials in a test session. The whole test comprised a total of 10 test sessions and there were 20 test trials of each presentation mode.

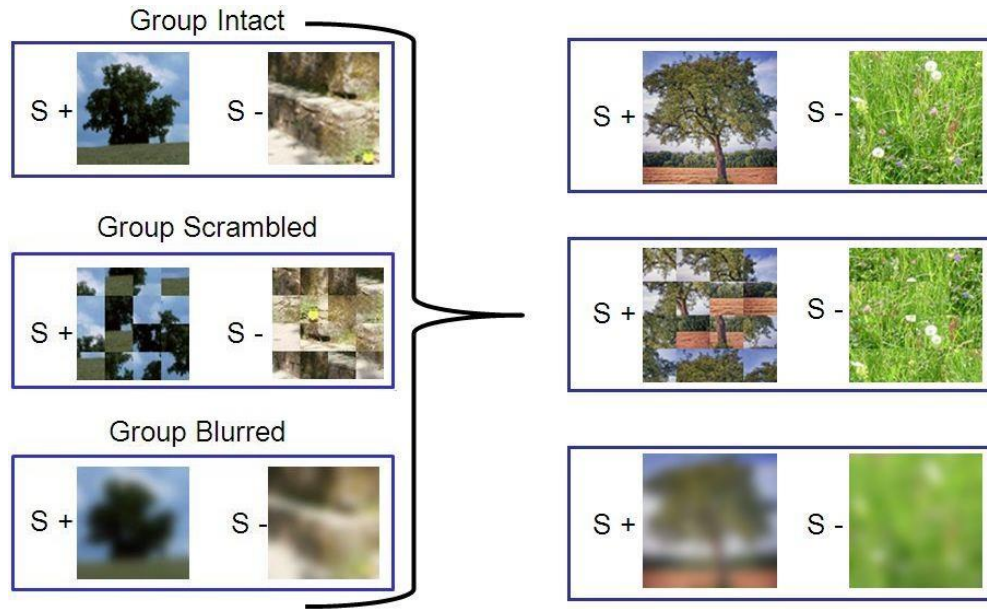


Figure 6: Examples of training (left) and transfer stimuli (right) of Test 5 shown for all three groups of the Categorization task.

2.4 Data analysis

As subjects were rewarded only for correct choices on training trials, one-sided binomial tests were used for data analysis ($\alpha = 0.05$). To obtain significance in training sessions, correct first choices had to be made in ≥ 15 out of the 20 trials ($p = 0.021$), equaling 75 %. The learning criterion was defined as significant performance in 8 out of 10 successive training sessions. Tests were analysed by assessing performance across all test trials (or types of test trials) presented in a particular test. In every test there were 20 test trials of a particular picture type. Thus, like in training, ≥ 15 correct first choices had to be obtained in order to indicate significance ($p = 0.021$), for a particular type of test stimuli.

Performance was analysed separately for each bird and at group level. Group-level analyses were carried out in two different ways with α always being 0.05. First, comparisons of performance between individual stimulus types were made by means of Wilcoxon- or Mann-Whitney U-Tests, carried out in SPSS. Wilcoxon-Tests were used for comparisons of performances across subjects of a group and Mann-Whitney U-Tests were applied when searching for differences between subjects of a group. Second, group analyses based on the p-values that had been calculated for the individual

subjects were done, which allowed for detecting also responding tendencies that may have been too weak to manifest in significant differences at the individual level or to show in the Mann-Whitney U- and Wilcoxon- Tests. To account for such tendencies, individual probabilities were combined using Fisher's method (see, e.g., Aust & Steurer, 2013; Huber et al., 2005; Sokal & Rohlf, 1995). To this end, each p-value was transformed into a χ^2 -value. The individual χ^2 -values were then added and thus resulted in a combined χ^2 -value from which significance at group level (i.e., a p-value) could be derived. In each test six χ^2 -values were added (six subjects per group), which meant 12 degrees of freedom. This was done separately for the results achieved for all test stimulus types and both tasks in each group.

3. Results

The individual results for all pigeons as well the averages of all groups ($\pm$ SD) in both tasks are listed in the Appendix (1. Individual results). The results of the tests are given as the number of correct first choices and are significant with ≥ 15 out of 20 correct first choices. The combined p-values of the group analyses (calculated by using Fisher's method) are also listed in the Appendix (2. Group analysis).

3.1 Training

The results of the training are shown in Figure 7. In both tasks the animals of Group Blurred needed more sessions to reach the learning criterion than those of Groups Intact and Scrambled. In the Categorization task the difference between Groups Intact and Blurred and between Groups Scrambled and Blurred was significant (Mann-Whitney U-Test: Int-Blur: $p \leq 0.01$; Scr-Blur: $p \leq 0.05$), whereas there was no difference between Groups Intact and Scrambled. This was also the case in the Identification task, with Group Blurred needing again significantly more sessions than Groups Intact and Scrambled (Mann-Whitney U-Test: both Int-Blur and Scr-Blur: $p \leq 0.01$), whereas there was no difference between Groups Intact and Scrambled. The animals of Groups Intact and Scrambled learnt the Categorization task significantly faster than the Identification task (Wilcoxon- Test: both groups: $p \leq 0.05$). This was not the case in Group Blurred,

which was probably due to one animal that needed more sessions to learn the rule-based than the rote learning task.

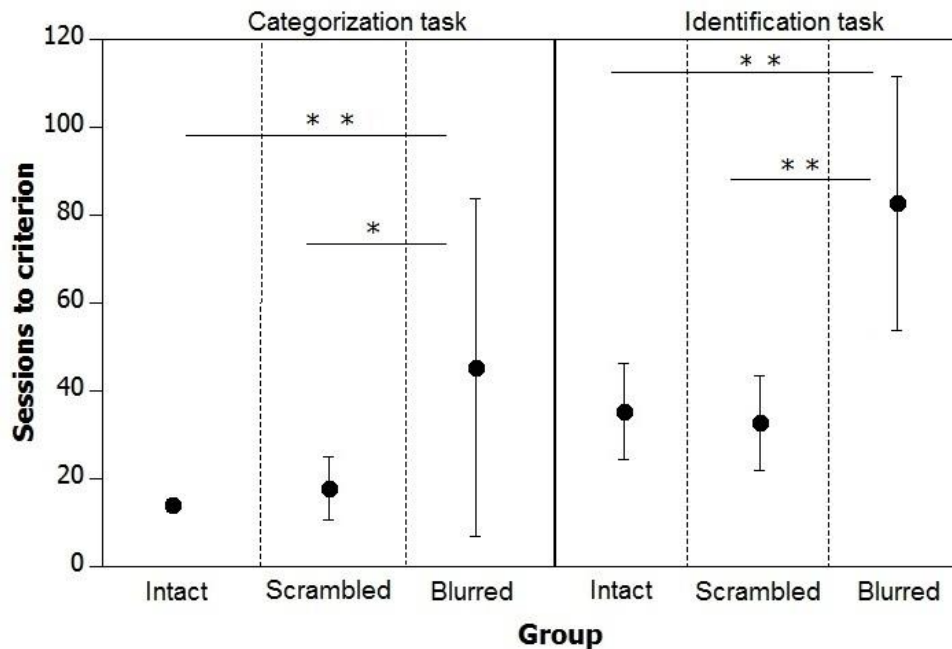


Figure 7: Mean ($\pm$ SD) numbers of sessions required by the animals of the three groups to reach the learning criterion, shown separately for the Categorization and the Identification task and the three presentation types.

3.2 Test 1: Transfer to the other presentation modes

The results of Test 1 are illustrated in Figure 8. In the Categorization task all pigeons of Group Intact were able to transfer to scrambled pictures whereas just two were successful in transferring to blurred pictures. Four out of six birds of Group Scrambled could transfer to intact stimuli, but just one to blurred pictures. In turn, no subject of Group Blurred was able to transfer to any other presentation type. Analysis showed that Groups Intact and Scrambled showed significant though not particularly good transfer to blurred pictures (Wilcoxon-Test; both p -values for transfer from Int to Blur and from Scr to Blur ≤ 0.05), but combined p -values analysis revealed quite good transfer of Group Intact to both other presentation types (transfer to Scr: $p \leq 0.0001$ and to Blur: $p \leq 0.001$) and the same was found for Group Scrambled (transfer to Int: $p \leq 0.0001$ and to Blur:

$p \leq 0.01$). Group Blurred showed no successful transfer even in combined p-values analysis. The highly significant transfer to blurred pictures in Groups Intact and Scrambled was obviously the result of the tendency of most animals pecking the correct stimuli in more than half of the trials which accumulated to a significance at group level. In the Identification task four pigeons of Group Intact transferred to scrambled pictures and all animals of Group Scrambled transferred to intact pictures. No bird of either group was able to recognize blurred pictures at a significant level. In Group Blurred just one subject transferred to intact and another one to scrambled pictures. So the results repeated (in an even more pronounced way) the ones of the Categorization task, because Groups Intact and Scrambled had problems transferring to blurred pictures and Group Blurred couldn't transfer to the other presentation types. Analysis by Fisher's method showed the same picture because Group Intact significantly transferred to scrambled and Group Scrambled transferred to intact picture types (both p-values ≤ 0.0001) and Group Blurred showed no significant transfer to any presentation type. The Wilcoxon-Test showed revealed no significant performance differences between any two picture types in any group. The comparison between the Categorization and the Identification task showed that Group Intact transferred better to blurred pictures of the Categorization than the Identification task (Wilcoxon-Test: $p \leq 0.05$). The other groups showed no significant differences between the tasks.

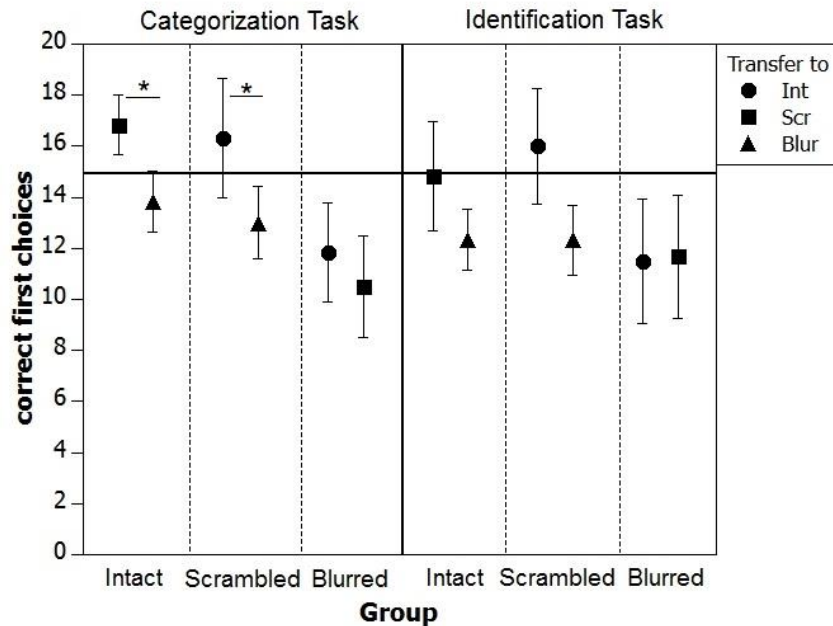


Figure 8: Performance in Test 1 for transfer to the two previously untrained presentation modes as number of correct first choices out of 20, shown separately for the two tasks and the three presentation types. Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Int = intact stimuli; Scr = scrambled stimuli; Blur = blurred stimuli.

3.3 Test 2: New scramble and blur degrees

The results of Test 2 of the Categorization task are shown in Figure 9. No pigeon, with the exception of one subject of Group Scrambled, was able to transfer to strongly scrambled pictures. Groups Intact and Scrambled showed the best performance with weakly scrambled picture types, with all subjects being able to make a significant transfer. Four animals of Group Intact significantly transferred to weakly blurred pictures but only two to strongly blurred pictures. In Group Scrambled two birds transferred significantly to both weakly and strongly blurred pictures. Group Blurred showed the best performance with blurred pictures. All animals of this group, except one, transferred significantly to weakly blurred pictures and four recognized strongly blurred pictures. Performance was worst with scrambled pictures of both degrees. Group level analysis confirmed that all groups showed better transfer to weakly than to strongly scrambled picture types (Wilcoxon-Test: all p-values: ≤ 0.05). Analysing the data using Fisher's

method showed that Groups Intact and Scrambled transferred to weakly scrambled pictures types (both p -values ≤ 0.0001) and to blurred pictures of both degrees (Group Intact: transfer to Blur strong: $p \leq 0.05$, Blur weak: $p \leq 0.0001$; Group Scrambled: both p -values ≤ 0.05). Group Blurred successfully transferred to blurred pictures of both degrees (both p -values ≤ 0.05).

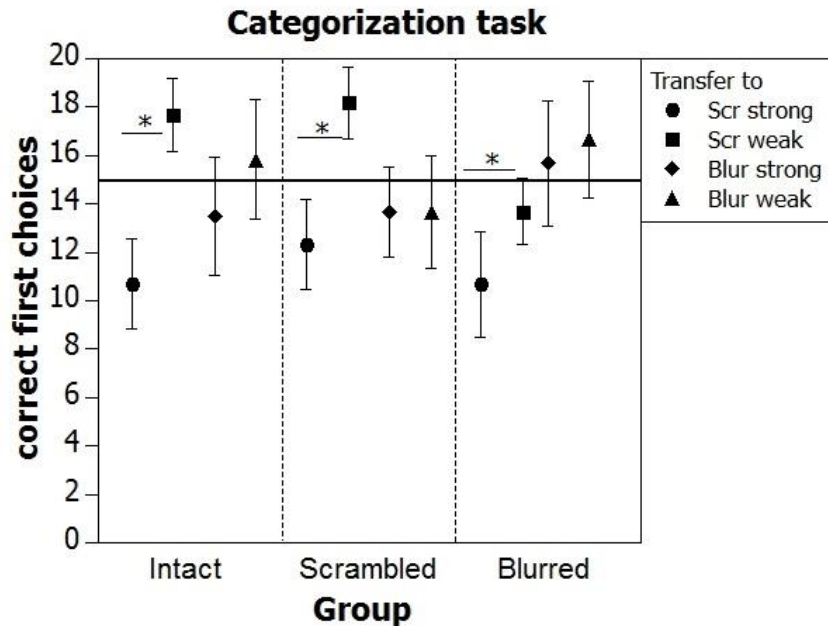


Figure 9: Performance in Test 2 for transfer to novel scramble and blur degrees in the Categorization task as number of correct first choices out of 20, shown separately for the three groups. Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Scr strong = strongly scrambled stimuli; Scr weak = weakly scrambled stimuli; Blur strong = strongly blurred stimuli; Blur weak = weakly blurred stimuli.

The results of the Identification task are illustrated in Figure 10. In this task no animal, with the exception of one subject of Group Scrambled, was able to transfer to strongly scrambled pictures. Again, Groups Intact and Scrambled performed best with weakly scrambled pictures. Five birds of Group Intact transferred to weakly blurred pictures but only one to strongly blurred pictures. Therefore Group Intact showed better transfer to weakly scrambled and blurred pictures than to either picture type when strongly modified (Wilcoxon-Test; all p -values ≤ 0.05). As in the Categorization task two pigeons of Group Scrambled transferred to blurred pictures of both degrees. But the results of Group

Blurred were different from those in the Categorization task because the group was not able to transfer to any test stimulus type. Only one animal transferred to blurred pictures of both degrees. Analysing the data using Fisher's method showed that all groups successfully transferred to weakly scrambled pictures (Groups Intact and Scrambled: both p -values ≤ 0.0001 , Group Blurred $p \leq 0.001$) and to blurred pictures of both degrees (Group Intact: Blur strong: $p \leq 0.001$ and Blur weak: $p \leq 0.0001$, Group Scrambled: both p -values $p \leq 0.001$, Group Blurred: both p -values $p \leq 0.00001$) and Group Scrambled even transferred to strongly scrambled pictures ($p \leq 0.05$).

The subjects showed better transfer in the Categorization task than in the Identification task. Group Scrambled could better transfer to weakly scrambled pictures (Wilcoxon-Test $p \leq 0.05$) in the Categorization than the Identification task and Group Blurred showed a better performance with both weakly and strongly blurred pictures in the Categorization than the Identification task (Wilcoxon-Test: both p -values ≤ 0.05)

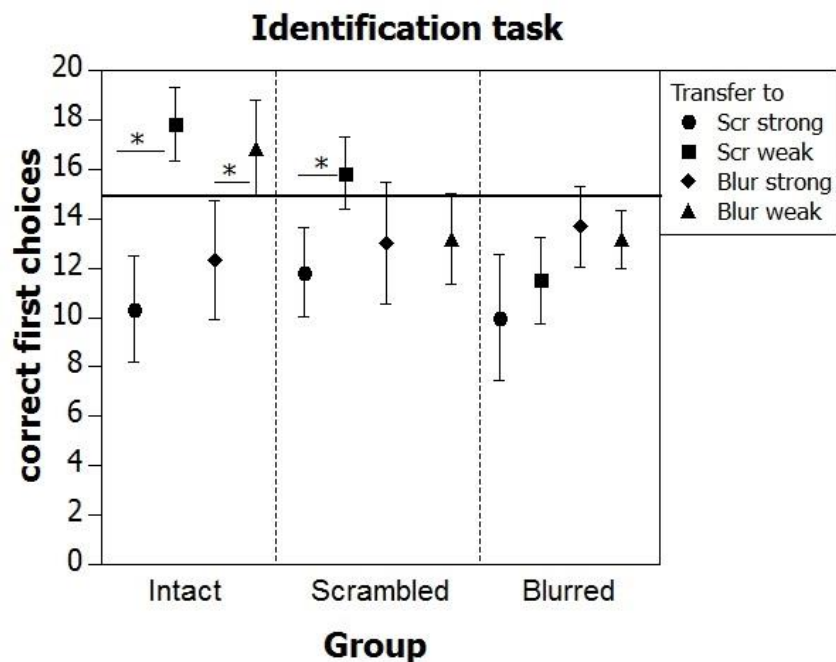


Figure 10: Performance in Test 2 for transfer to novel scramble and blur degrees in the Identification task as number of correct first choices out of 20, shown separately for the three groups. Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Scr strong = strongly scrambled stimuli; Scr weak = weakly scrambled stimuli; Blur strong = strongly blurred stimuli; Blur weak = weakly blurred stimuli.

In summary no group was able to transfer to strongly scrambled pictures. Group Intact transferred to weakly scrambled pictures and there was also a tendency for a transfer to weakly blurred pictures. Group Scrambled just transferred to weakly scrambled pictures, but not to other presentation types. Group Blurred made no transfer to scrambled pictures at any degree but showed a tendency to transfer to blurred picture of both degrees.

3.4 Test 3: Grayscale versions of all three picture types

The results of Test 3 are shown in Figure 11. In both tasks all groups failed to significantly transfer to grayscale versions. But in the Categorization task Group Intact, at least, showed a better performance with intact grayscale pictures than with blurred grayscale pictures (Wilcoxon-Test: Int gray-Blur gray: $p \leq 0.05$), with half of the pigeons transferring to grayscale intact but no animal transferring to grayscale blurred pictures. Furthermore, Group Scrambled showed better transfer to scrambled grayscale than to blurred grayscale pictures (Wilcoxon-Test: Scr gray-Blur gray: $p \leq 0.05$), and half the group significantly transferred to intact and scrambled stimuli, but no subject of the group transferred to blurred grayscale pictures. Group Blurred made no successful transfer to any presentation type, with the exception that one animal significantly transferred to intact and one to blurred pictures. Analysing the data at group level by using Fisher's method showed that Groups Intact and Scrambled successfully transferred to intact and scrambled grayscale pictures (Group Intact: transfer to Scr gray: $p \leq 0.05$, all other p -values ≤ 0.0001). Group Scrambled even transferred significantly to blurred grayscale pictures ($p \leq 0.05$) and also Group Blurred transferred to blurred grayscale pictures ($p \leq 0.01$). In the Identification task no Group showed significant transfer to any picture type when shown in grayscale. Group Intact showed the worst transfer to blurred grayscale pictures (Wilcoxon-Test: Int gray-Blur gray: $p \leq 0.05$). There were no differences in performance between the presentation modes in the other groups. Performance of Group Intact in recognizing grayscale blurred pictures was significantly better in the Categorization than in the Identification task ($p \leq 0.05$), but the other groups showed no significant differences.

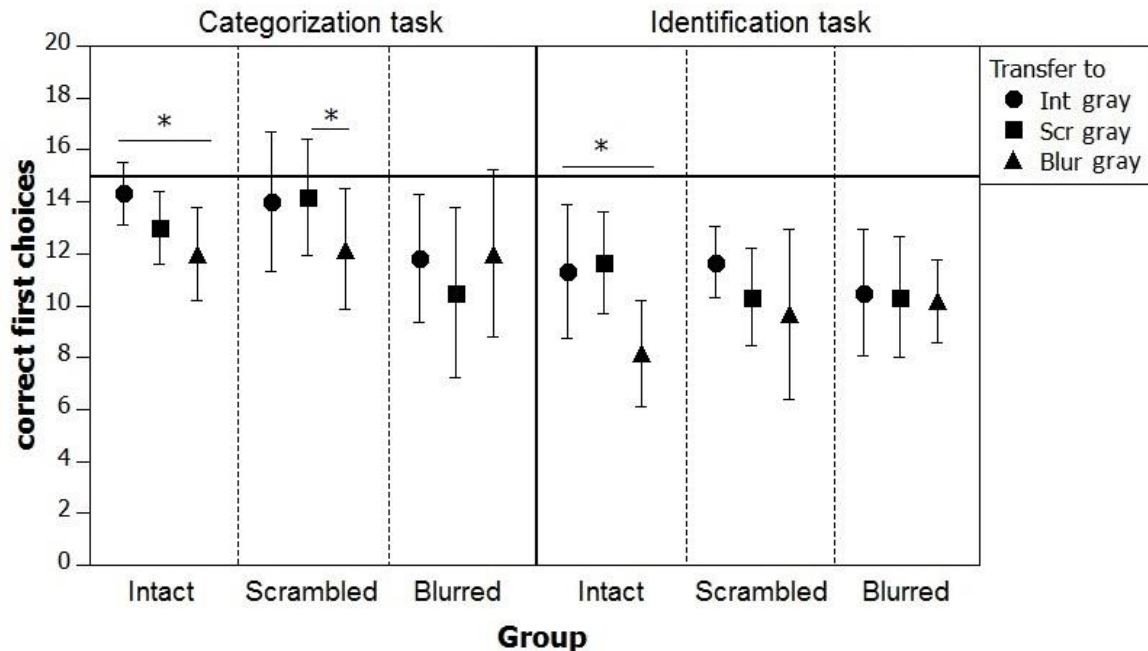


Figure 11: Performance in Test 3 for transfer to grayscale versions as number of correct first choices out of 20, shown separately for the two tasks and the three presentation types. Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Int gray = grayscale intact stimuli; Scr gray = grayscale scrambled stimuli; Blur gray = grayscale blurred stimuli.

3.5 Test 4: Both blurred and scrambled pictures

Figure 12 illustrates the results of Test 4, in which the pigeons were confronted with pictures which had first been blurred and then scrambled. The results show that in the Categorization task all groups failed to transfer to these pictures, and with Fisher's method only Group Scrambled was significant ($p \leq 0.01$), probably because two pigeons were able to make a successful transfer. In the Identification task all but one bird of Group Blurred could significantly transfer to the test stimuli and the group's performance differed significantly from performance of Group Intact where just one subject was successful (Mann-Whitney U-Test: $p \leq 0.05$). Half the animals of Group Scrambled were able to transfer to the test stimuli. The analysis using Fisher's method yielded significance for all groups (Group Intact: $p \leq 0.05$; Groups Scrambled and Blurred: both p-values $p \leq 0.0001$). There were no significant differences in performance between the two tasks in Groups Intact and Scrambled, but Group Blurred performed better in the Identification than in the Categorization task (Wilcoxon-Test: $p \leq 0.05$).

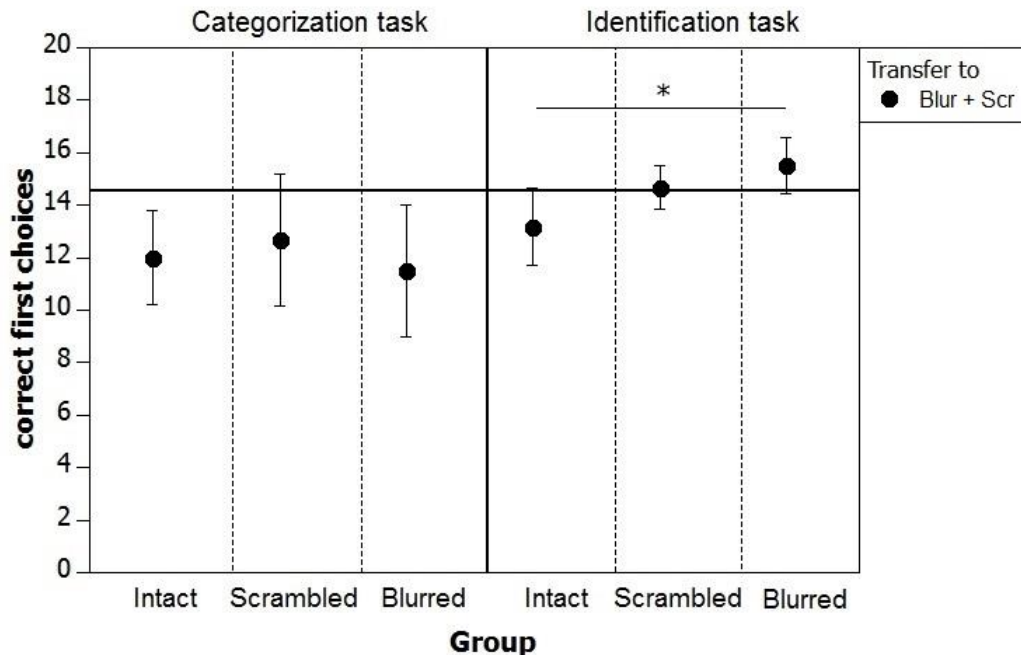


Figure 12: Performance in Test 4 for transfer to pictures that were both scrambled and blurred, as number of correct first choices out of 20, shown separately for the two tasks and the three presentation types. Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Blur + Scr = both blurred and scrambled stimuli.

3.6 Test 5: Novel category instances

The results of Test 5 are shown in Figure 13. Groups Intact and Scrambled had no problem transferring to novel intact or scrambled tree and nontree pictures. But in both groups transfer to blurred pictures was poor. For Group Intact the difference in performance between novel intact and novel blurred stimuli was significant (Wilcoxon-Test: Int nov-Blur nov: $p \leq 0.05$) and for Group Scrambled the difference in performance between novel scrambled and novel blurred pictures was significant (Wilcoxon-Test: Scr nov-Blur nov: $p \leq 0.05$). In Group Blurred five out of six pigeons were able to transfer to novel blurred pictures, three transferred to novel intact, and only two transferred to novel scrambled. Analysing the data using Fisher's method yielded significance to all novel picture types for all groups (Group Intact: transfer to Blur nov: $p \leq 0.01$, Group Scrambled transfer to Blur nov: $p \leq 0.001$, all other transfers: p -values ≤ 0.0001 .)

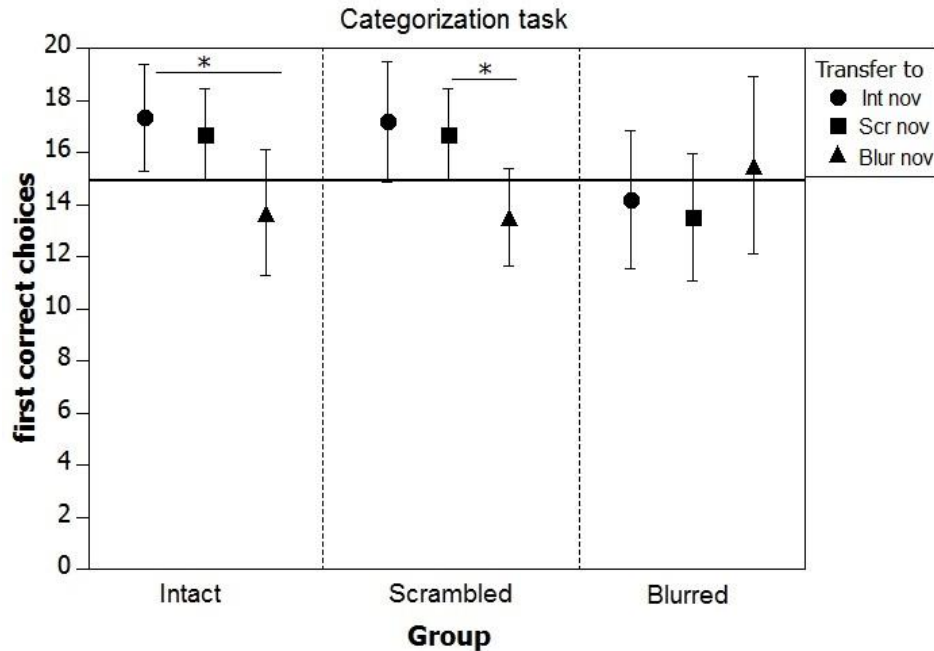


Figure 13: Performance in Test 5 for transfer to novel instances of the tree and nontree categories in the Categorization task as number of correct first choices out of 20, shown separately for the three presentation types. Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Int nov = novel intact stimuli; Scr nov = novel scrambled stimuli; Blur nov = novel blurred stimuli.

4. Discussion

The main results of Experiment 1 can be summarized as follows: 1) Overall, the pigeons learnt the Categorization task faster than the Identification task and also in the tests the animals performed better in the Categorization task than in the Identification task (with the exception of Test 4). 2) In both tasks the pigeons of Group Blurred needed more sessions to reach the learning criterion than the subjects of Groups Intact and Scrambled. 3) The transfer from intact to scrambled pictures and vice versa was possible but the birds couldn't transfer from and to blurred stimuli (Test 1). 4) Some limitation to the birds' capacity to recognize scrambled pictures was shown in Test 2. There, neither group could transfer to strongly scrambled pictures. 5) Another finding was that color is important for the birds' ability to recognize pictures, because all animals showed poor transfer to grayscale pictures (Test 3). 6) For the most part, the pigeons

failed to generalize to pictures that were both blurred and scrambled (Test 4). 7) The last test (Test 5) showed that the pigeons seemed to use a strategy, which is beyond learning the stimuli by rote on a pixel-by-pixel basis to solve the Categorization task, because they could generalize to novel instances of the two classes. Therefore it is possible that the animals used a perceptual rule.

The fact that the animals learnt the task in which they could use a rule to discriminate the pictures faster than the rote learning task indicates that rote learning is only the secondary strategy for pigeons, as suggested by Cook and Smith (2006). Considering better test performance in the Categorization task, it seems that not only acquisition during training but also transfer abilities were enhanced by the perceptual rule. But this advantage didn't exist when the birds were confronted with pictures which were both scrambled and blurred (Test 4). In this test the animals achieved better results in the rote learning task. (A possible explanation for this will be offered further below).

To show that (with the exception of Test 4) faster learning and better transfer didn't occur because pigeons can discriminate photographs (Categorization task) better than artificial stimuli (Identification task) another group of control pigeons was trained and tested with a Pseudocategory task in an follow-up experiment which was, however, not part of the present thesis anymore. There, pictures of trees and nontrees were arbitrarily defined as positives or negatives so that the pigeons had to learn them by rote. It was found that the control animals learning the Pseudocategory task needed more sessions to reach the learning criterion than the experimental subjects needed to learn the Categorization task, and, most interesting, even more sessions than the experimental subjects needed to learn the Identification task. Also, the results obtained in the tests following Pseudocategory training were similar to the ones obtained in the Identification task. This is clear evidence that the use of photographs in the Categorization task was not the reason for faster learning and better transfer in the experimental subjects.

Overall, the experiment showed that local information is critical for pigeons' ability to learn and categorize visual stimuli, which was also reported in other studies (Cavoto & Cook, 2001; Gibson et al., 2005). Furthermore, my study revealed that there seemed to be a "transfer barrier", which impeded transfer from and to blurred pictures, meaning that Groups Intact and Scrambled couldn't transfer to blurred pictures and Group Blurred only transferred to their own picture type (i.e., blurred) but not to the other two picture

types (Test 5). The result that Group Blurred could transfer to blurred, but not to intact pictures, although the latter also contained intact global information strongly suggests that the animals didn't use global information at all. It seems that they "insisted" on using degraded local information, which was also present in blurred pictures. The fact that the transfer barrier from and to blurred stimuli was found for both tasks indicates that local information is important for both learning pictures by rote and abstracting a perceptual rule. Most likely, the use of degraded local information was also the reason why Group Blurred needed so many sessions to reach the learning criterion. In turn, Groups Intact and Scrambled learned faster probably because they could use intact local information, and this may also have enabled them to transfer to the presentation type of the other group but prevented transfer to blurred pictures, which contained only degraded local information.

Pigeons' bias to use local information could be rooted in their visual system. Pigeons have two specialized fovea in their eyes, which have different functions. The frontal visual field is specialized for binocular perception of the visual space immediately in front of the bird. So it has presumably evolved for myoptic foraging for food on the ground and it is suggested to be sensitive for local information. The second one is called the lateral visual field and it is specialized for wide field monocular perception of the visual area around and lateral to each side of the animal. This field has presumably evolved for predator detection and flight control and it is suggested that it might be more sensitive to global information (Cook, 2001). Considering that, it could well be that the screen in the Skinner box was too close to the pigeons to encourage them to use the lateral field. Instead, these confined conditions could have favored the use of the frontal visual field for inspecting the stimuli. As a consequence, the birds would have focused mainly on local details but widely neglected the global configuration of the pictures. An experiment conducted by Cook and colleagues (unpublished, but it was explained in Cook, 2001) seems to support this hypothesis: When he moved the display monitor away from the viewing monitor the birds started to prefer global information over local information.

Another outcome of the present experiment was that pigeons' ability to recognize pictures also depended on the degree of scrambling and blurring. No group was able to transfer to strongly scrambled pictures. This means that the local details in these pictures were too strongly fragmented for the birds to recognize them anymore.

Therefore this test confirmed previous findings of pigeons' ability to recognize scrambled pictures decreasing with increasing degrees of scrambling (Aust & Huber, 2001; Goto et al., 2011). Decreasing the degree of blurring had a positive effect on picture recognition, with nearly all animals of Groups Intact and even some of Group Scrambled being able to transfer to weakly blurred pictures. This was obviously due to the fact that in these stimuli local information was degraded to a lesser extent than in the blurred stimuli of the first test, which allowed the pigeons to use the local level more efficiently than in Test 1. Groups Intact and Scrambled also showed a good transfer to weakly scrambled pictures. A reason for this good performance and the bad transfer to strongly scrambled pictures could be that local details, which were used by the birds of both groups, were intact in weakly scrambled pictures, but were destroyed by a higher scrambled degree. But the fact that Group Blurred wasn't able to transfer even to weakly scrambled and (at least in the Identification task) to weakly blurred pictures suggests that the transfer barrier from blurred pictures to the other presentation modes still remained. A reason for the bad performance with weakly blurred pictures could lie in the pigeon's use of degraded local information in training stimuli of Group Blurred. It seems that Group Blurred learnt to focus on this specific type of local information and therefore the birds were unable to handle any change of this grade of local information.

The importance of color for pigeons' ability to discriminate pictures was shown by using grayscale pictures (Test 3). In this test no group was able to transfer to the test stimuli in either tasks. Therefore, these results support earlier evidence for pigeons' reliance on color information in visual tasks (Aust & Huber, 2001; Aust & Huber, 2010; Aust & Steurer, 2013; Huber et al., 2000; Loidolt et al., 2003; Kirsch et al., 2008; Troje et al., 1999).

Obviously, the negative effects of the individual picture manipulations (scrambling or blurring) added up when both manipulations were applied at the same time (Test 4), and even outweighed any advantages that were possibly provided by the perceptual rule, because in this test the Identification task had a better performance than the Categorization task. A reason for this result could be the differences between the two tasks regarding color composition. The pictures of the Categorization task contained a lot of green, brown and blue color shades (at least to the human eye), and it could be that after both scrambling and blurring the pictures, the subjects couldn't discriminate

them anymore because of their similar colors. By contrast, every stimulus of the Identification task had its unique color composition, which decreased the risk of confusing them even when the pictures were strongly modified. So the pigeons could have solved this test by using color cues, which was easier in the Identification than in the Categorization task. A problem of this account is, however, that in Test 2 the birds could obviously not take advantage of color information in the Identification task when confronted with strongly scrambled pictures.

The results of Test 5 support the assumption that the birds had indeed used the tree/nontree rule, but also showed that this ability was limited by the transfer barrier outlined above: Groups Intact and Scrambled were able to generalize to novel intact and scrambled pictures but not to novel blurred pictures, and Group Blurred could generalize only to novel blurred stimuli.

In summary, the experiment confirmed pigeons' bias to use local information. The fact that there was no difference in performances between the two tasks leads to the conclusion that the category structure had no effect on pigeons' choice of processing level. Furthermore, it was revealed that there was a transfer barrier from and to blurred pictures, because Groups Intact and Scrambled just transferred to intact and scrambled pictures and Group Blurred only recognized blurred pictures. Thus there are differences in picture perception between pigeons and humans, because humans were shown to be able to transfer from the local to the global level and vice versa (Aust & Braunöder, submitted; Schwaninger et al., 2002), whereas pigeons obviously "insist" on focusing on local information, even when it is degraded. The obvious question to investigate next was thus whether this transfer barrier would fall if only the pigeons could be "pushed" to use global information. In support of this hypothesis, previous studies showed that the birds indeed started to focus on the global level when presented with pictures reduced in size or when the distance between subject and picture was increased (Cook, 2001; Goto et al., 2004). To investigate if a reduction of stimulus size would lead to improved transfer from and to blurred stimuli, Experiment 2 was conducted.

Experiment 2

1. Introduction

The first experiment confirmed pigeons' bias to process pictures at the local level. But it cannot be excluded that this result was an artifact of the experimental design. The animals in the first experiment were located very closely (approximately 3-4 cm) to the stimuli, so maybe the pictures were too big for the pigeons to detect the global structure. Using the example of the art museum again, it is the same when you are standing too close to a big picture and just see parts of it whereas you are able to see it as a whole if you take some steps back. This assumption is also in keeping with the finding that pigeons started to process the global level when the stimulus size was reduced or the distance between display and subject was increased (Cook, 2001; Goto et al., 2004). With our set-up it was technically not possible to increase the viewing distance between the birds and the stimuli. Instead, I reduced the edge length of the original stimuli by half. To be able to make comparisons between Experiment 1 and 2 the trainings and tests of the first experiment were repeated with novel subjects and a test was added in which the pigeons were confronted with the pictures in original size, shown in all three presentation modes.

2. Methods

2.1 Subjects and apparatus

For the second experiment 18 novel homing pigeons (*Columbia livia domestica*) of mixed sex were used. The housing and feeding situation and the apparatus were the same as in the first experiment.

2.2 Stimuli and procedure

The pictures were the same as the ones used in Experiment 1, with the exception that they were smaller. The stimuli had a size of 56 x 56 pixels, resulting in a size of 1.48 x 1.48 cm on the screen (Figure 14) and were therefore about a quarter the area of the original stimuli.



Figure 14: The left picture shows an example of the picture size of the first experiment and the right one shows the same picture after the reduction. The pictures have the same size as they were shown to the pigeons on the screen.

Again, there were three subject groups which were trained either with intact, scrambled or blurred pictures and they had to conduct the same tasks and tests as the subjects of the first experiment. To investigate if the birds were able to transfer from the small to the large pictures an additional test (Test 6) was administered in which the pigeons were confronted with the pictures of Experiment 1, shown in all presentation modes (Int large, Scr large, Blur large; Figure 15). In each test session of Test 6 two training trials were replaced by the original (i.e., large) versions of the respective stimuli. Each test session contained 18 training trials and six test trials so one test session contained 24 trials. The whole test comprised a total of 10 test sessions and there were 20 test trials of each presentation type. During the second experiment one pigeon (Mr. Speckle) of Group Intact died, thus Test 6 was completed only by five birds of this group.

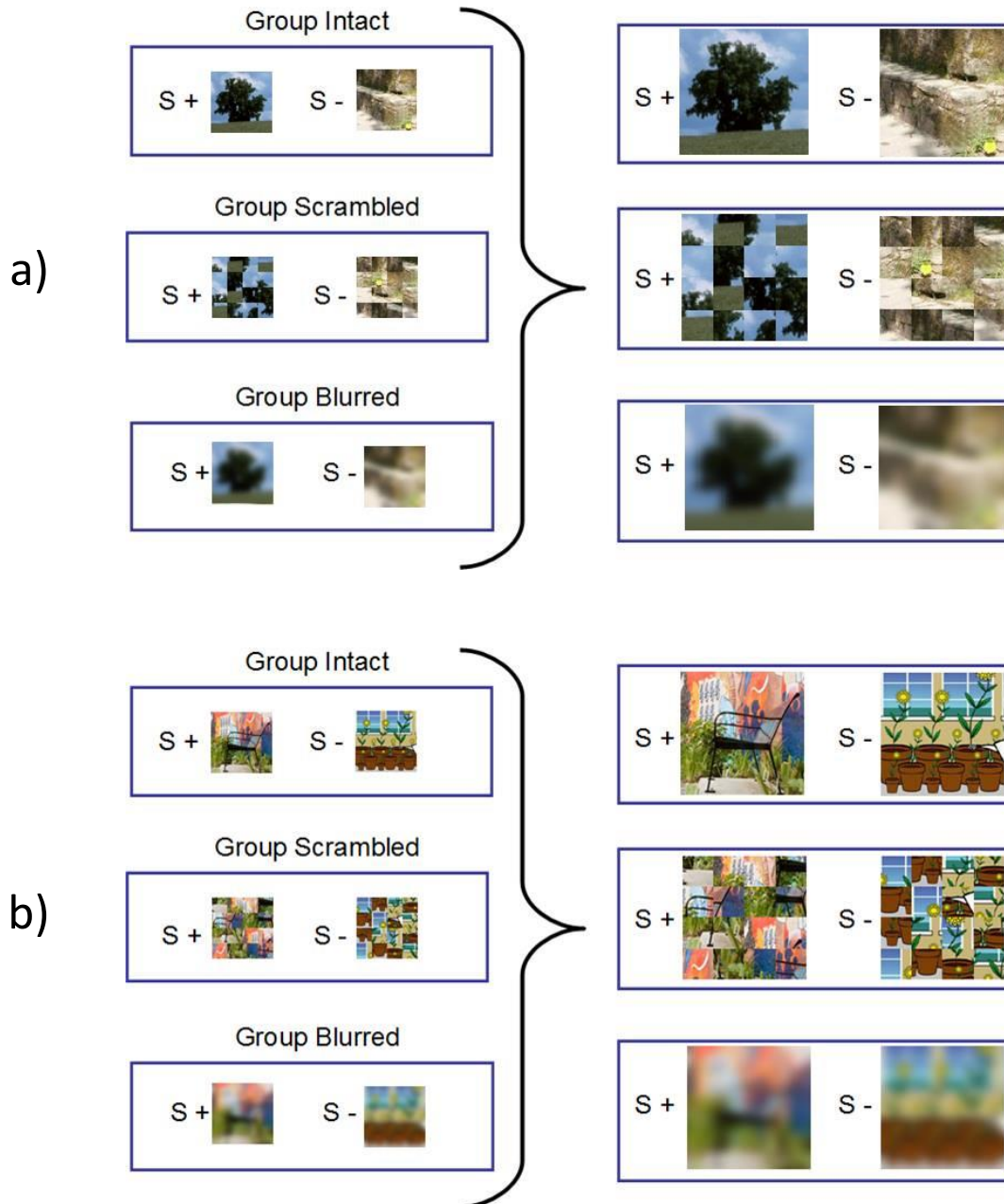


Figure 15: Examples of training (left) and transfer stimuli (right) in Test 6 for transfer from small to large pictures, shown separately for all three groups, and for the Categorization (a) and the Identification task (b).

2.3 Data analysis

Data were analysed in the same way as in the first experiment. For the comparison between animals trained with large and small pictures group level analysis were carried out by comparing the performance between individual stimulus types by means of Mann-Whitney U-Tests. Further the data of the groups of one task were pooled and then

comparisons of performances between individual stimulus types between the first and the second experiment were made by means of Mann-Whitney U-Tests.

3. Results

The individual results for all pigeons as well the averages of all groups ($\pm$ SD) in both tasks are listed in the Appendix (1. Individual results). The results of the tests are given as the number of correct first choices and are significant with ≥ 15 out of 20 correct first choices. The combined p-values of the group analyses (calculated by using Fisher's method) are also listed in the Appendix (2. Group analysis).

3.1 Training

The results of the training are shown in Figure 16. The data revealed no significant differences between the groups in either task, although Group Blurred needed most sessions to reach the learning criterion in both tasks. Group Scrambled needed significantly less sessions in the Categorization than the Identification task (Wilcoxon-Test: $p \leq 0.05$) whereas the other two groups showed no significant differences between the two tasks regarding learning speed. On group level the comparison between the animals which were trained with the large pictures (Experiment 1) and the ones trained with small pictures (Experiment 2) also showed no significant differences in the sessions they needed to reach the criterion and also the comparison with pooled data showed no differences.

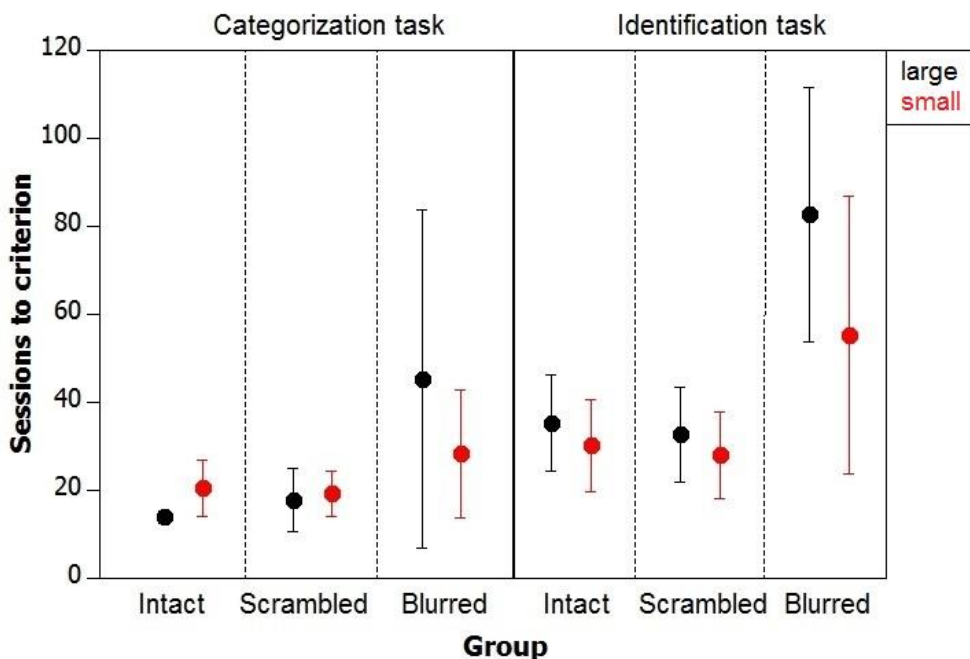


Figure 16: Mean ($\pm$ SD) numbers of sessions required by the three groups to reach the learning criterion, shown separately for the Categorization and the Identification task and the three presentation types. The graph shows the results obtained from the animals trained with original picture size (large) in Experiment 1 and the ones trained with reduced picture size (small) in Experiment 2. Means were taken across the animals of each group.

3.2 Test 1: Transfer to the other presentation modes

The results of Test 1 are illustrated in Figure 17. In the Categorization task all subjects of Group Intact transferred to scrambled pictures and half of them recognized blurred pictures. All birds of Group Scrambled (except one) showed successful transfer to intact, but no pigeon recognized blurred pictures and, at group level, the difference in transfer to intact and to blurred pictures was significant (Wilcoxon-Test. $p \leq 0.05$). Only one pigeon of Group Blurred transferred to intact and another one to scrambled pictures. But analysing the data using Fisher's method showed that Group Intact significantly transferred to both presentation types (both p -values ≤ 0.0001), Group Scrambled transferred to intact pictures ($p \leq 0.0001$) and even Group Blurred made a significant transfer to intact pictures ($p \leq 0.05$).

In the Identification task the results show a similar picture. All subjects of Group Intact transferred to scrambled stimuli and all but two had significant results with the blurred pictures. In Group Scrambled four out of six animals were able to transfer to intact stimuli, but only two transferred to blurred. Only one bird of Group Blurred significantly transferred to intact stimuli, and no pigeon of that group could recognize scrambled pictures. Analysing the data with Fisher's method showed that Group Intact transferred significantly to scrambled and blurred pictures (both $p\text{-values} \leq 0.0001$), Group Scrambled transferred successfully to intact and scrambled stimuli (transfer to Int: $p \leq 0.0001$, transfer to Blur: $p \leq 0.001$, all other $p\text{-values} \leq 0.0001$) and Group Blurred significantly transferred to intact pictures ($p \leq 0.001$). Group Intact showed better transfer to scrambled pictures in the Identification than the Categorization task (Wilcoxon-Test: $p \leq 0.05$), whereas the other groups showed no significant differences in performance between the two tasks and there

In summary, there seemed to be a tendency that the animals trained with small pictures performed somewhat better, but this was significant only for Group Intact in the Identification task. There, the birds trained with small pictures (Experiment 2) showed significantly better transfer to blurred pictures than the subjects trained with large pictures (Experiment 1; Mann-Whitney U-Test: $p \leq 0.05$). But it has to be mentioned that the absolute performance of Group Intact with blurred pictures in Experiment 2 was still not above the level of significance. There were no significant differences when the data of the groups were pooled.

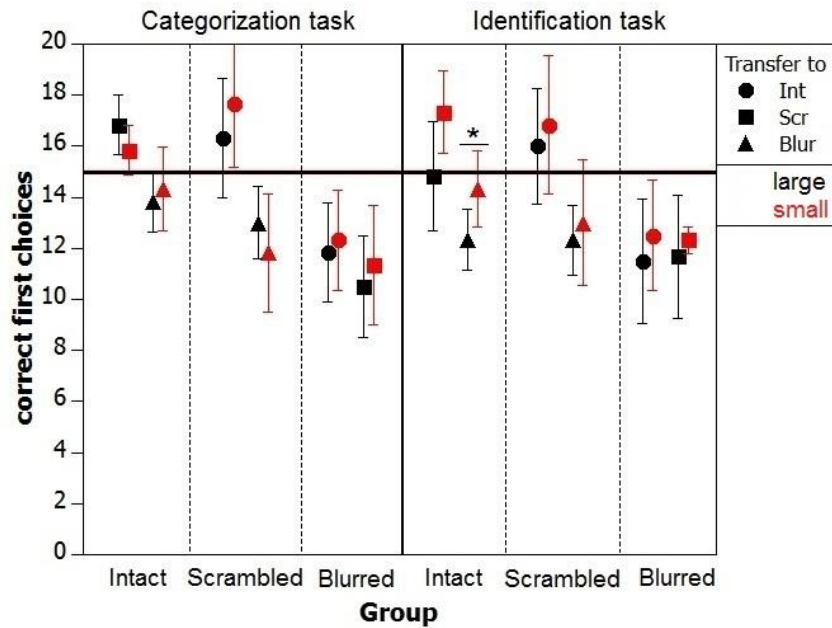


Figure 17: Performance in Test 1 for transfer to the two previously untrained presentation modes shown as number of correct first choices out of 20, and separately for the two tasks and the three presentation types. The graph shows the results obtained from the animals trained with original picture size (large) and the ones trained with reduced picture size (small). Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Int = intact stimuli; Scr = scrambled stimuli; Blur = blurred stimuli.

3.3 Test 2: New scramble and blur degrees

The results of Test 2 in the Categorization task are shown in Figure 18. All Groups showed worst performance with strongly scrambled pictures. Just three birds, two of Group Intact and one of Group Blurred, were able to transfer to this presentation mode. Half the animals of Group Intact transferred to weakly scrambled pictures, four birds had significant results with strongly blurred stimuli and all subjects significantly transferred to weakly blurred stimuli. Group Scrambled showed best performance compared to all presentation modes with weakly scrambled and blurred pictures, with five out of six birds transferring to these picture types, and this group had the worst results compared to all presentation modes with strongly scrambled and blurred stimuli. Only one animal was able to recognize strongly blurred pictures, and no subject transferred significantly to strongly scrambled stimuli. Transfer in this group was significantly better with weakly blurred pictures than with strongly blurred ones (Wilcoxon-Test: Blur low-Blur high:

$p \leq 0.05$). Group Blurred had the best results compared to all presentation modes with blurred pictures in both degrees, with all birds significantly transferring to strongly blurred pictures, and all but one bird significantly transferring to weakly blurred pictures. Only two animals showed significant transfer to weakly scrambled pictures and only one recognized strongly scrambled stimuli. But analysing the results with Fisher's method showed that all groups significantly transferred to all presentation modes, with the exception of Group Blurred, which showed no transfer to strongly scrambled stimuli (Group Scrambled transfer to: Scr strong: $p \leq 0.05$, Blur strong: $p \leq 0.01$; Group Blurred transfer to: Scr weak: $p \leq 0.001$, all other p-values ≤ 0.0001).

There are only few differences between the performances of the animals of the two experiments. In Experiment 2 Group Intact showed significantly better transfer to strongly scrambled pictures, but worse in transfer to weakly scrambled pictures than the subjects of Experiment 1 (Mann-Whitney U-Test: Scr strong: $p \leq 0.05$, Scr weak: $p \leq 0.05$). Group Scrambled of the second experiment was significantly better regarding transfer to weakly blurred pictures than the subjects of the first experiment (Mann-Whitney U-Test: Blur weak: $p \leq 0.05$). Groups Blurred of the two experiments showed no significant differences. Analysing the data by pooling the results of the groups showed only one significant difference in the transfer to strongly scrambled pictures. Here the animals of the second experiment had better results than the animals trained with large pictures (Mann-Whitney U-Test: Scr high: $p \leq 0.05$).

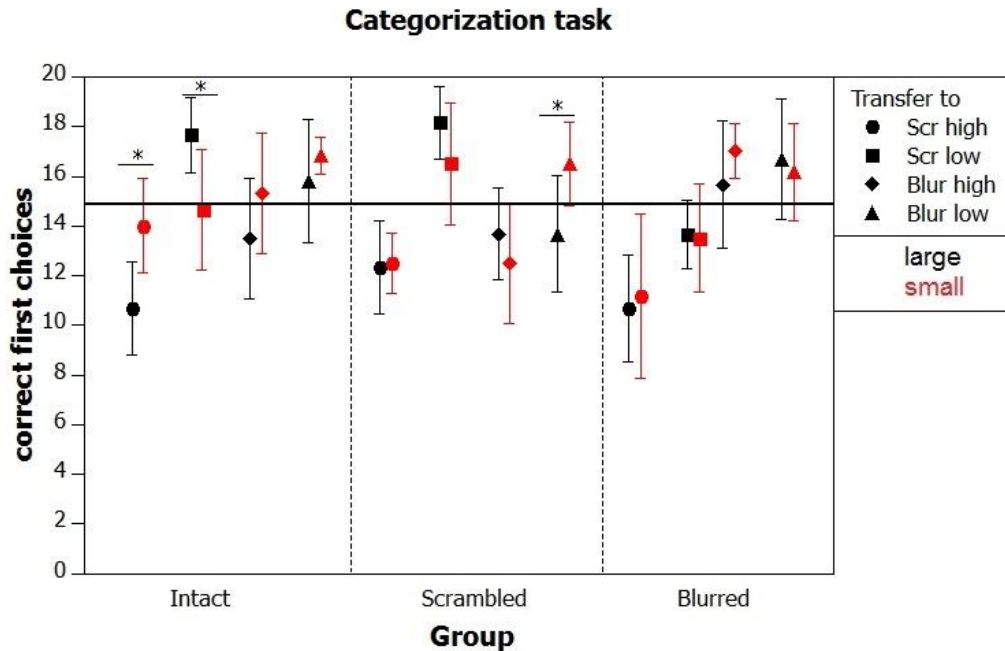


Figure 18: Performance in Test 2 for transfer to novel scramble and blur degrees in the Categorization task shown as number of correct first choices out of 20, and separately for the three groups. The graph shows the results obtained from the animals trained with original picture size (large) and the ones trained with reduced picture size (small). Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Scr strong = strongly scrambled stimuli; Scr weak = weakly scrambled stimuli; Blur strong = strongly blurred stimuli; Blur weak = weakly blurred stimuli.

The results of the Identification task are illustrated in Figure 19. Only one animal of Group Intact significantly transferred to strongly scrambled stimuli, all but one recognized weakly scrambled and strongly blurred pictures and all showed significant transfer to weakly blurred stimuli. Thus, also at group level, performance was better with weakly scrambled than with strongly scrambled pictures (Wilcoxon-Test: Scr weak - Scr strong: $p \leq 0.05$), but there were no significant differences between weakly and strongly blurred pictures. The results of Group Scrambled were similar, with only one pigeon recognizing strongly scrambled pictures. All subjects significantly transferred to weakly scrambled and blurred pictures and five out of six birds recognized strongly blurred stimuli. The group's performance with weakly scrambled pictures was significantly better than with strongly scrambled stimuli (Wilcoxon-Test: Scr weak - Scr strong: $p \leq 0.05$) and there were no differences between the two degrees of blurred stimuli. No animal of Group Blurred significantly transferred to strongly scrambled pictures. Four out of six

pigeons significantly transferred to weakly scrambled stimuli as well as to both weakly and strongly blurred pictures. Accordingly, also transfer performance at group level was significantly better with weakly scrambled than with strongly scrambled stimuli (Wilcoxon-Test: Scr weak - Scr strong: $p \leq 0.05$), but there were no significant differences between weakly and strongly blurred pictures. Analysing the data using Fisher's method revealed significant transfer of all groups to weakly scrambled stimuli and to strongly and weakly blurred pictures. Significant transfer to strongly scrambled stimuli was only found for Group Scrambled (Group Scrambled: transfer to Scr strong: $p \leq 0.05$; Group Blurred: transfer to Scr weak: $p \leq 0.001$, all other p-values ≤ 0.0001). Although there seemed to be some tendency that Groups Scrambled and Blurred of Experiment 2 (small pictures) showed better transfer than the corresponding groups of the Experiment 1 (large stimuli), the only significant difference between the two experiments was found for transfer to weakly scrambled stimuli. There, transfer in Group Blurred of the second experiment was better than in Group Blurred of the first (Mann-Whitney U-Test: Scr weak: $p \leq 0.05$), but it should be mentioned that the absolute performance of Group Blurred in the transfer to weakly scrambled pictures of the second experiment was not above the level of significance. Analysing the data by pooling the results of the groups showed that the birds trained with small pictures had better transfer to blurred pictures in both degrees than the pigeons trained with large pictures (Mann-Whitney U-Test: both p-values ≤ 0.05).

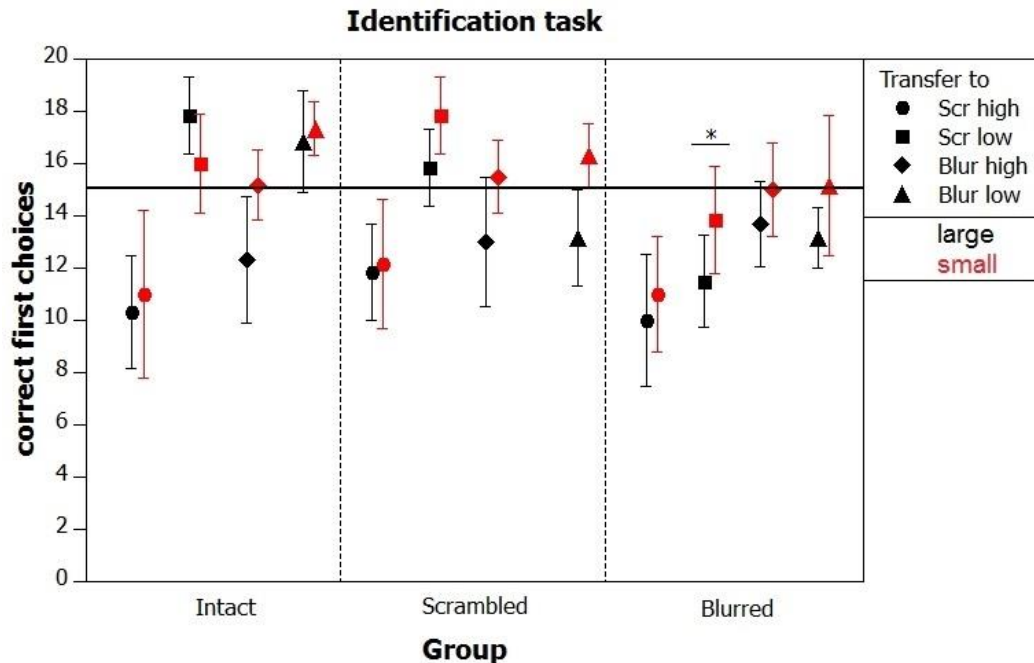


Figure 19: Performance in Test 2 for transfer to novel scramble and blur degrees in the Identification task, shown as number of correct first choices out of 20 and separately for the three groups. The graph shows the results obtained from the animals trained with original picture size (large) and the ones trained with reduced picture size (small). Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Scr strong = strongly scrambled stimuli; Scr weak = weakly scrambled stimuli; Blur strong = strongly blurred stimuli; Blur weak = weakly blurred stimuli.

In summary, no group successfully transferred to strongly scrambled pictures in either task. Groups Intact and significantly transferred to weakly scrambled and blurred pictures and there was also a non-significant tendency for transfer to strongly blurred pictures. Group Blurred showed no transfer to scrambled pictures at either degree, but significantly transferred to both weakly and strongly blurred pictures.

3.4 Test 3: Grayscale versions of all three picture types

The results of Test 3 are shown in Figure 20. Overall, all groups showed poor transfer to grayscale pictures in both tasks. In the Categorization task only one animal of Group Intact significantly transferred to intact grayscale pictures, no animal transferred to scrambled grayscale stimuli and four out of six pigeons of Group Intact significantly transferred to blurred grayscale pictures. No subject of Group Scrambled significantly

recognized intact grayscale pictures, half the birds significantly transferred to scrambled grayscale pictures and only one significantly transferred to blurred stimuli. One animal of Group Blurred showed significant transfer to intact and scrambled grayscale stimuli and two recognized blurred grayscale pictures. Analysing the data using Fisher's method showed that, as a group, the subjects of Group Intact significantly transferred to grayscale pictures in all presentation modes (transfer to Int gray: $p \leq 0.001$; to Scr gray: $p \leq 0.05$; to Blur gray: $p \leq 0.0001$), those of Group Scrambled significantly transferred to scrambled and those of Group Blurred to blurred pictures (both p -values ≤ 0.0001).

In the Identification task only one animal of Group Intact significantly transferred to intact grayscale pictures and one bird of Group Blurred was significant with intact and scrambled grayscale pictures. All other subjects failed to transfer to grayscale stimuli, irrespective of presentation mode. Group Scrambled showed better performance with intact than with blurred grayscale pictures (Wilcoxon-Test: $p \leq 0.05$), all other groups showed no significant differences. Analysing the data using Fisher's Method showed that Groups Intact and Scrambled showed significant transfer to intact grayscale pictures (both p -values ≤ 0.05), but there were no significant differences between the other presentation modes and there were no differences in Group Blurred. Groups Intact and Blurred transferred better to blurred grayscale pictures in the Categorization task than in the Identification task (Wilcoxon-Test: both p -values ≤ 0.05), but there were no differences in the transfer to other presentation types and Group Scrambled showed no significant differences at all. There were no significant differences between the performances of the animals trained with large and small pictures on group level and when the data of the groups were pooled.

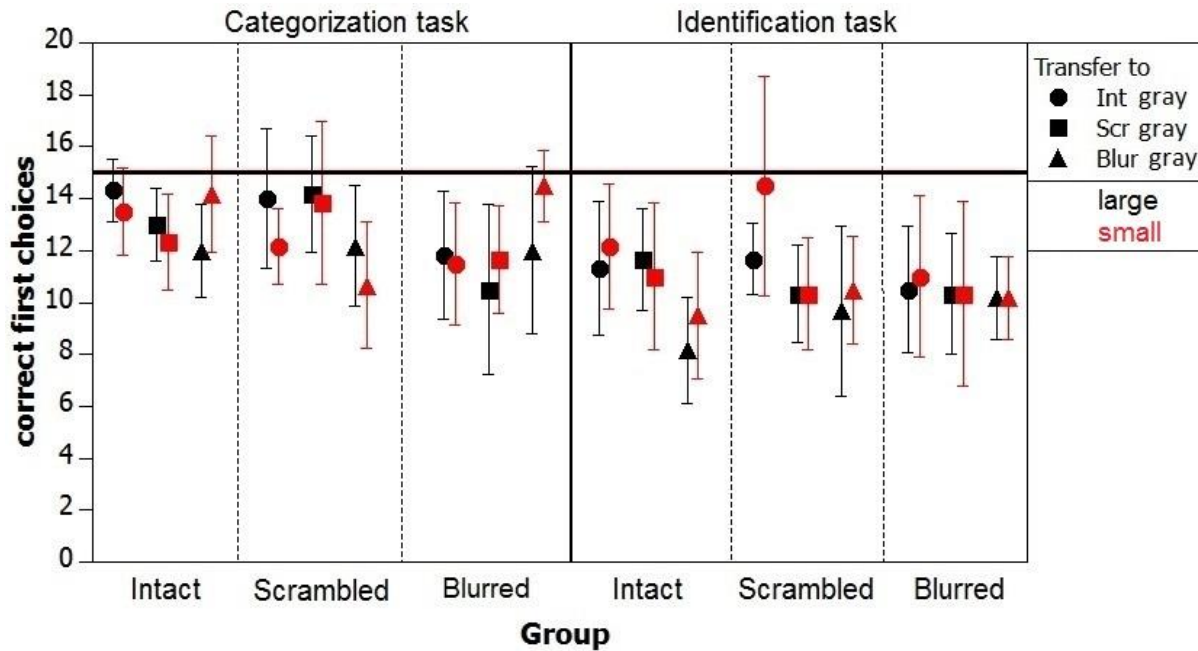


Figure 20: Performance in Test 3 for transfer to grayscale versions shown as number of correct first choices out of 20 and separately for the two tasks and the three presentation types. The graph shows the results obtained from the animals trained with original picture size (large) and the ones trained with reduced picture size (small). Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Int gray = grayscale intact stimuli; Scr gray = grayscale scrambled stimuli; Blur gray = grayscale blurred stimuli.

3.5 Test 4: Both blurred and scrambled pictures

The results of Test 4 are illustrated in Figure 21. In the Categorization task half the birds of Groups Intact and Scrambled were able to transfer significantly to stimuli that were both blurred and scrambled, whereas only one animal of Group Blurred was able to do so. Group Scrambled performed significantly better than Group Blurred (Mann-Whitney U-Test: $p \leq 0.05$). In the Identification task the results were similar but here four out of six pigeons of Groups Intact and Scrambled and half the birds of Group Blurred significantly transferred to the test stimuli. Analysing the data using Fisher's method showed that groups made significant transfer in both tasks (Categorization task: Group Blurred: $p \leq 0.001$, all other p -values in both tasks $p \leq 0.0001$). Although there were no significant differences between the subjects trained with small pictures (Experiment 2) and the ones trained with large pictures (Experiment 1) on group level, after analysing

the pooled data of the groups it was shown that in the Categorization task the animals of the second experiment had better results than the pigeons of the first (Mann-Whitney U-Test: Blur + Scr: $p \leq 0.05$).

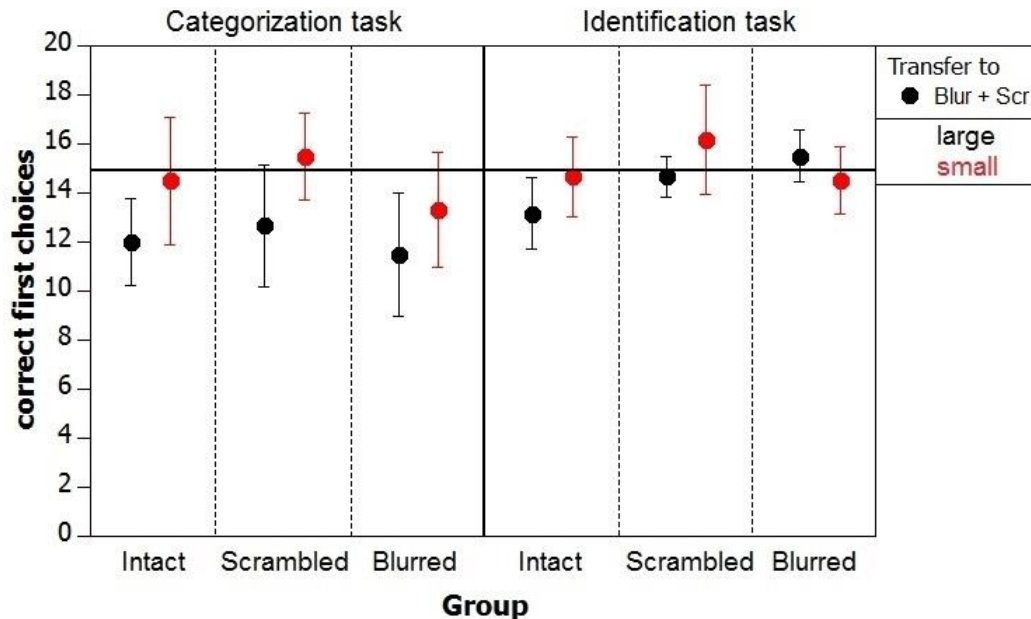


Figure 21: Performance in Test 4 for transfer to pictures that were both scrambled and blurred, shown as number of correct first choices out of 20 and separately for the two tasks and the three presentation types. The graph shows the results obtained from the animals trained with original picture size (large) and the ones trained with reduced picture size (small). Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Blur + Scr = stimuli that were both blurred and scrambled.

3.6 Test 5: Novel category instances

The results of Test 5 are shown in Figure 22. All animals of Group Intact significantly transferred to intact stimuli and all except one were successful with blurred pictures and only two transferred significantly to scrambled stimuli. Analysing the data on group level showed no significant differences. In Group Blurred it was the other way round, with all birds transferring to blurred and all but one subject transferring to intact pictures. Only two birds of Group Blurred recognized novel scrambled stimuli and, at group level, the difference in performance between scrambled and blurred pictures was significant

(Wilcoxon-Test: $p \leq 0.05$), but there were no other significant differences. Interestingly, Group Scrambled showed best transfer to intact pictures, with performance of five out of six pigeons being significant. Half of the group recognized blurred stimuli, and only two subjects had significant results with scrambled pictures and analysing the results on group level showed no significant differences. Analysing the data using Fisher's Method showed that all groups made a successful transfer to all picture types (Group Blurred transfer to Scr nov: $p \leq 0.01$, all other p -values: ≤ 0.0001). There were no significant differences in performances between the animals trained with large (Experiment 1) and small pictures (Experiment 2) neither by analysing the data on group level nor by pooling the data of the groups.

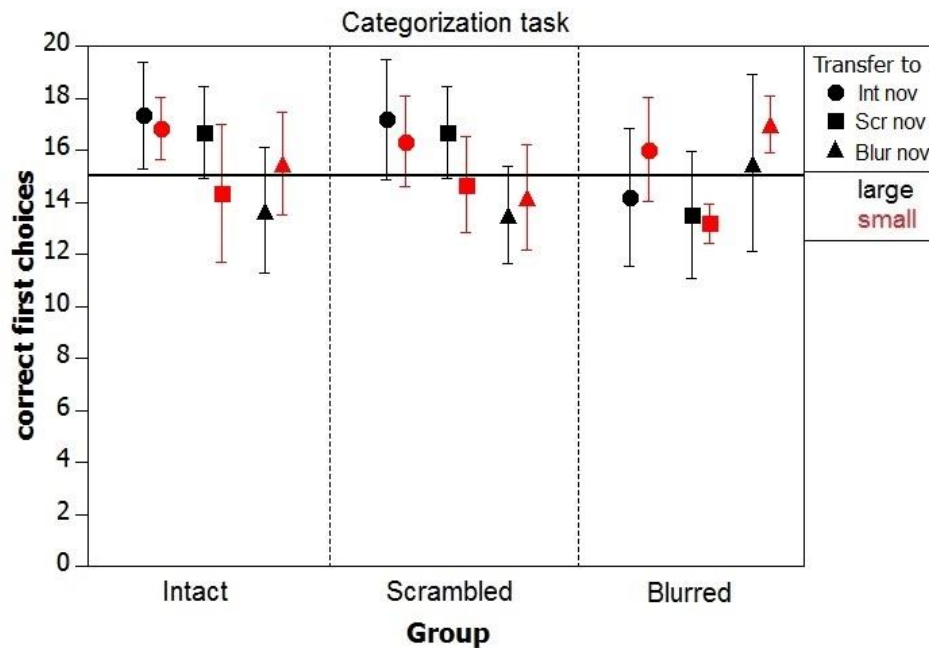


Figure 22: Performance in Test 5 for transfer to novel instances of the tree and nontree categories in the Categorization task, shown as number of correct first choices out of 20 and separately for the three presentation types. The graph shows the results obtained from the animals trained with original picture size (large) and the ones trained with reduced picture size (small). Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Int nov = novel intact stimuli; Scr nov = novel scrambled stimuli; Blur nov = novel blurred stimuli.

3.7 Test 6: Original picture size

The results of Test 6 are illustrated in Figure 23. This test was carried out with only five animals of Group Intact, because one bird (Mr. Speckle) had died. In the Categorization task all animals of Group Intact showed significant transfer to large intact and scrambled pictures and two transferred to large blurred stimuli. All birds of Group Scrambled significantly transferred to large scrambled pictures, four pigeons recognized large intact pictures, but only one was significant with large blurred stimuli. Group Blurred showed best performance with blurred pictures, because all subjects except one were able to recognize them, whereas only two birds significantly transferred to large intact and one to large scrambled pictures. The subjects of Group Blurred transferred significantly better to blurred than to scrambled stimuli (Wilcoxon-Test: $p \leq 0.05$), but there were no further significant differences neither in this group nor in the others. Analysing the data with Fisher's method revealed significant transfer to all presentation modes for all groups (Group Scrambled transfer to Blur large: $p \leq 0.001$, Group Blurred transfer to Scr large: $p \leq 0.001$, all other p-values $p \leq 0.0001$).

In the Identification task all birds of Group Intact except one significantly transferred to large intact stimuli, three out of five animals significantly transferred to large scrambled pictures, but only two recognized large blurred stimuli. Accordingly, also performance at group level was better with large intact than with large blurred stimuli (Wilcoxon-Test: $p \leq 0.05$), but there were no other significant differences. In Group Scrambled four out of six subjects significantly transferred to large intact pictures, all but one recognized large scrambled stimuli, but only one was successful with blurred pictures. Accordingly, also performance at group level was better with large scrambled than with large blurred pictures (Wilcoxon-Test: $p \leq 0.05$), again there were no other significant differences. Only one animal of Group Blurred significantly transferred to large intact and scrambled pictures and half the group successfully recognized large blurred pictures. Group analyses by Fisher's Method showed that all groups significantly transferred to all presentation modes (Group Intact transfer to Blur large: $p \leq 0.001$; Group Scrambled transfer to Blur large: $p \leq 0.05$; Group Blurred: transfer to Int large: $p \leq 0.001$, transfer to Scr large: $p \leq 0.05$, all other p-values: ≤ 0.0001).

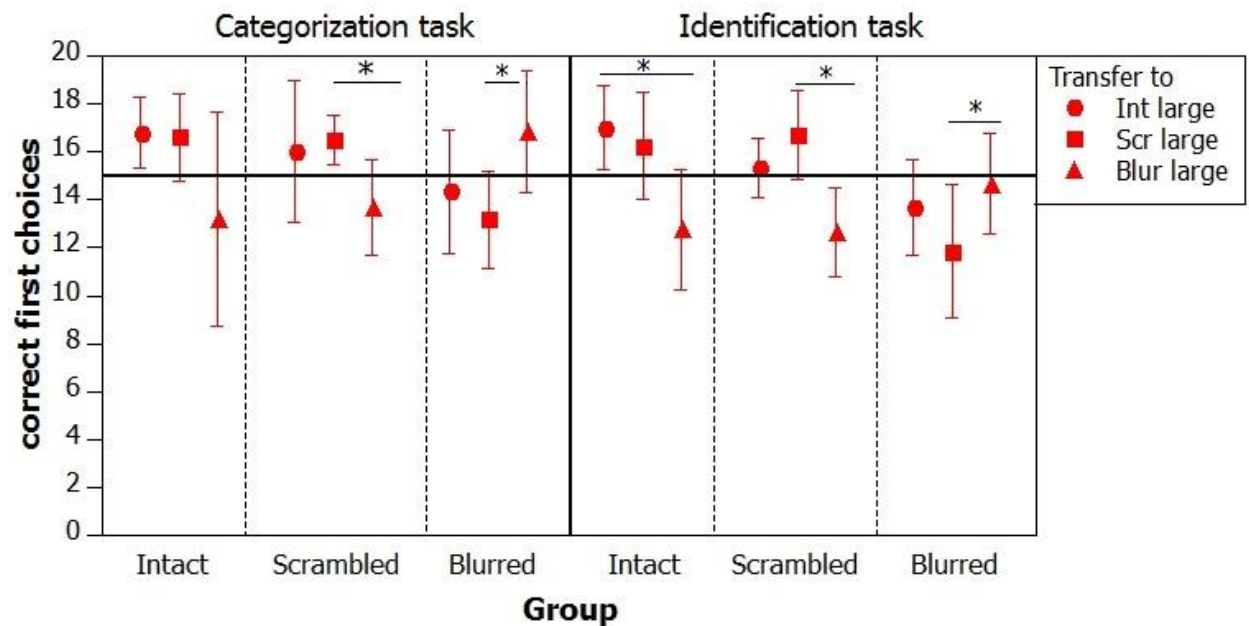


Figure 23: Performance in Test 6 for transfer to the large versions of the stimuli (used in Experiment 1), shown as number of correct first choices out of 20 and separately for the two tasks and the three presentation types. Means ($\pm$ SD) were taken across the animals of each group. The horizontal line indicates the limit of significance. Int large = original sized intact stimuli; Scr large = original sized scrambled stimuli; Blur large = original sized blurred stimuli.

4. Discussion

The second experiment showed that the reduction of the pictures led, at least in some cases, to a shift towards global processing level. For example in the Categorization task Group Scrambled trained with small pictures showed a significantly better performance in the transfer to weakly blurred stimuli than the group trained with large pictures. Further when the results of the groups of the Identification task were pooled the animals confronted with reduced picture size showed better performances in the transfer to strongly and weakly blurred pictures (Test 2) than the animals trained with the original size. So it seems that at least in these cases the animals were able to shift their attention towards global information. But the experiment also revealed that the shift from local to global processing level wasn't strong enough to let the transfer barrier from local to global disappear. Groups Intact and Scrambled were able to transfer to intact and scrambled stimuli types in both picture sizes (Test 1 and Test 6). Further they were only

able to transfer to blurred pictures, when the grade of blurring was reduced (Test 2), but in the other tests (Tests 1, 5 and 6) there was no significant transfer. Group Blurred's inability to transfer to intact and scrambled pictures, even when the degree of scrambling was reduced, remained and they were only successful in recognizing their own (blurred) presentation mode in both picture sizes (Tests 1, 2, 5 and 6).

One reason why the animals didn't show a strong shift in all tests toward global information processing, as did the pigeons in the experiments conducted by Cook and colleagues (unpublished, but it was explained in Cook, 2001) could lie in the difference distances between pigeons and stimuli. In Cook's experiment he increased the distance, and the birds were able to concentrate on the global level, but the animals in my second experiment were at the same distance to the stimuli as the pigeons in the first experiment. It could be possible that by reducing the stimuli at a quarter of the original size, the pictures remained too large for the animals to detect the global structure of the pictures and they focused on local details.

Another factor could be the position of the stimuli. Pigeons are emmetropic in the upper visual field (Fitzke et al., 1985) and become myopic in the lower visual field (Fitzke et al., 1985; Hodos & Erichsen, 1990). If a picture is positioned in the lower visual field and the pigeon is in some distance (Cook had the best results in the shift to global level at a distance of 6.5 cm in his experiment which is explained in Cook, 2001) to the stimuli, the animal may not be able to see details of the stimulus and must rely on global information instead. The pigeons in Cook's study (unpublished, but it was explained in Cook, 2001) may thus have perceived the stimuli with the lower visual field and because Cook increased the distance between bird and stimuli, the animals couldn't see the stimuli sharply and therefore used the global level. By contrast, the pigeons in the present study were close to the stimuli, and could thus see the details sharply focused (like in a foraging situation) so that there was no need for them to use global information (i.e., to switch to their "flight control and predator detection" mode).

From the results of Experiment 2 it can be concluded that, at least in the present experimental design, the reduction of the picture size was not sufficient to encourage the animals to use the global processing level to an extent that allowed for overcoming the transfer barrier from and to blurred stimuli. Further investigation needs to be done in which not only the distance between subject and stimuli but also the position of the

stimuli varies, to see if and when the animals start to switch from one processing level to the other.

General discussion

To summarize the results of the experiments I will concentrate on the three important questions, which I mentioned in the Introduction of the study. At first it was shown that in both experiments the category structure had no influence on the choice of processing level. The hypothesis that pigeons may use local information to memorize specific details of a stimulus (Identification task) and may rely on global information to find a category-defining target (Categorization task) couldn't be verified, because the birds used in both tasks local information to solve the tasks. Therefore both experiments confirmed the notion of a local precedence effect in pigeons, which was also found in other studies (Cavoto & Cook, 2001; Cerella, 1980; Gibson et al., 2005). Furthermore, my study revealed that there seemed to be a transfer barrier, which impeded transfer from and to blurred pictures, meaning that Groups Intact and Scrambled couldn't transfer to blurred pictures and Group Blurred only transferred to their own picture type (i.e., blurred) but not to the other two picture types. The result that Group Blurred could transfer to blurred, but not to intact pictures, although the latter also contained intact global information strongly suggests that the animals didn't use global information at all. It seems that they insisted on using degraded local information, which was also present in blurred pictures. At last it couldn't be shown that by reducing the stimuli size about a quarter of the original picture size of Experiment 1 that the animals could be pushed to use global rather than local information. Although there were cases in which the animals trained with reduced stimuli were able to process global information better than the animals trained with original sized pictures (for example, Test 2), the shift wasn't strong enough to overcome the transfer barrier from and to blurred stimuli. Therefore the birds' bias to use local information remained. Finally the question if pigeons are able to transfer from local to global information, as humans can do, can't be answered, because of the animals' refusal to use global information. It could be that the birds can make the transfer if they would start to focus on both information levels, but in my study they couldn't be forced to do so.

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Appendix

1. Individual results

Table 1: Sessions required to reach criterion in Experiment 1, listed for all subjects of all groups in the Categorization and Identification tasks.

Original picture size		Categorization Task	Identification Task
Group	Subject	Sessions to Criterion	Sessions to Criterion
Intact	Casper	14	39
	Cordula	13	29
	Franz	14	45
	Hoopoe	12	46
	Solitaire	16	36
	Trisha	15	17
	Mean ($\pm$ SD)	14 ($\pm$ 1.4)	35.3 ($\pm$ 11)
Scrambled	Bobbison	12	43
	Gino	12	21
	Heinz	14	21
	Judith	31	39
	Lucy	19	44
	Yeti	18	28
	Mean ($\pm$ SD)	17.7 ($\pm$ 7.2)	32.7 ($\pm$ 10.7)
Blurred	Art	15	62
	Arthur	64	77
	Cindy	21	51
	Tino	22	79
	Vanessa	115	93
	Verena	34	134
	Mean ($\pm$ SD)	45.2 ($\pm$ 38.4)	82.7 ($\pm$ 29)

Table 2: Sessions required to reach criterion in Experiment 2, listed for all subjects of all groups in the Categorization and Identification tasks.

Small picture size		Categorization Task	Identification Task
Group	Subject	Sessions to Criterion	Sessions to Criterion
Intact	Dr. House	28	19
	Mandy	20	24
	Mata Hari	28	44
	Mr. Speckle	12	20
	Snape	16	36
	Toby	19	38
	Mean ($\pm$ SD)	20.5 ($\pm$ 6.4)	30.2 ($\pm$ 10.5)
Scrambled	Claire	14	15
	George	29	31
	Harry	19	26
	Ida	19	20
	Lynn	16	33
	Penny	19	43
	Mean ($\pm$ SD)	19.3 ($\pm$ 5.2)	28 ($\pm$ 10)
Blurred	Emil	25	50
	Keira	17	36
	Klara	56	113
	Mag	29	44
	Martina	27	66
	William	16	23
	Mean ($\pm$ SD)	28.3 ($\pm$ 14.6)	55.3 ($\pm$ 31.7)

Table 3: Results of the individual birds of the Categorization task in Test 1 of Experiment 1, shown as correct first choices for all groups and both tasks. Significant results are given in bold. Int = intact pictures; Scr = scrambled pictures; blur = blurred pictures.

Original picture size		Categorization Task		
		Transfer to		
Group	Subject	Int	Scr	Blur
Intact	Casper	-	15	15
	Cordula	-	17	14
	Franz	-	16	12
	Hoopoe	-	18	14
	Solitaire	-	17	13
	Trisha	-	18	15
	Mean ($\pm$ SD)		16.9 ($\pm$ 1.2)	13.8 ($\pm$ 1.2)
Scrambled	Bobbison	19	-	14
	Gino	14	-	11
	Heinz	18	-	12
	Judith	13	-	13
	Lucy	17	-	13
	Yeti	17	-	15
	Mean ($\pm$ SD)	16.3 ($\pm$ 2.3)		13.0 ($\pm$ 1.4)
Blurred	Art	9	7	-
	Arthur	14	11	-
	Cindy	13	11	-
	Tino	13	10	-
	Vanessa	12	13	-
	Verena	10	11	-
	Mean ($\pm$ SD)	11.8 ($\pm$ 1.9)	10.5 ($\pm$ 2.0)	

Table 4: Results of the individual birds of the Identification task in Test 1 of Experiment 1, shown as correct first choices for all groups and both tasks. Significant results are given in bold. Int = intact pictures; Scr = scrambled pictures; blur = blurred pictures.

Original picture size		Identification Task		
		Transfer to		
Group	Subject	Int	Scr	Blur
Intact	Casper	-	15	11
	Cordula	-	16	13
	Franz	-	16	11
	Hoopoe	-	17	14
	Solitaire	-	14	12
	Trisha	-	11	13
	Mean ($\pm$ SD)		14.8 ($\pm$ 2.1)	12.3 ($\pm$ 1.2)
Scrambled	Bobbison	12	-	14
	Gino	18	-	13
	Heinz	17	-	12
	Judith	15	-	13
	Lucy	18	-	10
	Yeti	16	-	12
	Mean ($\pm$ SD)	16.0 ($\pm$ 2.3)		12.3 ($\pm$ 1.4)
Blurred	Art	16	9	-
	Arthur	10	10	-
	Cindy	11	10	-
	Tino	11	14	-
	Vanessa	9	15	-
	Verena	12	12	-
	Mean ($\pm$ SD)	11.5 ($\pm$ 2.4)	11.7 ($\pm$ 2.4)	

Table 5: Results of the individual birds of the Categorization task in Test 1 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int = intact pictures; Scr = scrambled pictures; blur = blurred pictures.

Small picture size		Categorization Task		
		Transfer to		
Group	Subject	Int	Scr	Blur
Intact	Dr. House	-	17	15
	Mandy	-	15	16
	Mata Hari	-	15	12
	Mr. Speckle	-	15	16
	Snape	-	16	13
	Toby	-	17	14
	Mean ($\pm$ SD)		15.8 ($\pm$ 1.0)	14.3 ($\pm$ 1.6)
Scrambled	Claire	18	-	8
	George	19	-	14
	Harry	17	-	13
	Ida	20	-	13
	Lynn	19	-	13
	Penny	13	-	10
	Mean ($\pm$ SD)	17.7 ($\pm$ 2.5)		11.8 ($\pm$ 2.3)
Blurred	Emil	12	9	-
	Keira	12	9	-
	Klara	9	11	-
	Mag	13	11	-
	Martina	15	13	-
	William	13	15	-
	Mean ($\pm$ SD)	12.3 ($\pm$ 2.0)	11.3 ($\pm$ 2.3)	

Table 6: Results of the individual birds of the Identification task in Test 1 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int = intact pictures; Scr = scrambled pictures; blur = blurred pictures.

Small picture size		Identification Task		
		Transfer to		
Group	Subject	Int	Scr	Blur
Intact	Dr. House	-	18	15
	Mandy	-	16	13
	Mata Hari	-	19	15
	Mr. Speckle	-	15	16
	Snape	-	17	15
	Toby	-	19	12
	Mean ($\pm$ SD)		17.3 ($\pm$ 1.6)	14.3 ($\pm$ 1.5)
Scrambled	Claire	19	-	12
	George	19	-	17
	Harry	17	-	12
	Ida	14	-	11
	Lynn	19	-	11
	Penny	13	-	15
	Mean ($\pm$ SD)	16.8 ($\pm$ 2.7)		13.0 ($\pm$ 2.4)
Blurred	Emil	12	13	-
	Keira	11	12	-
	Klara	10	13	-
	Mag	12	12	-
	Martina	14	12	-
	William	16	12	-
	Mean ($\pm$ SD)	12.5 ($\pm$ 2.2)	12.3 ($\pm$ 0.5)	

Table 7: Results of the individual birds of the Categorization task in Test 2 of Experiment 1, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Scr strong = strongly scrambled stimuli; Scr weak = weakly scrambled stimuli; Blur strong = strongly blurred stimuli; Blur weak = weakly blurred stimuli.

Original picture size		Categorization Task			
		Transfer to			
Group	Subject	Scr strong	Scr weak	Blur strong	Blur weak
Intact	Casper	9	19	13	13
	Cordula	10	19	9	16
	Franz	11	18	15	18
	Hoopoe	14	18	14	13
	Solitaire	11	15	14	16
	Trisha	9	17	16	19
	Mean ($\pm$ SD)	10.7 ($\pm$ 1.9)	17. ($\pm$ 1.5)	13.5 ($\pm$ 2.4)	15.8 ($\pm$ 2.5)
Scrambled	Bobbison	15	19	16	13
	Gino	14	20	12	14
	Heinz	11	18	12	13
	Judith	12	16	13	10
	Lucy	12	19	13	15
	Yeti	10	17	16	17
	Mean ($\pm$ SD)	12.3 ($\pm$ 1.9)	18.2 ($\pm$ 1.5)	13.7 ($\pm$ 1.9)	13.7 ($\pm$ 2.3)
Blurred	Art	12	14	18	19
	Arthur	13	13	12	18
	Cindy	12	14	16	17
	Tino	8	13	19	17
	Vanessa	11	12	14	12
	Verena	8	16	15	17
	Mean ($\pm$ SD)	10.7 ($\pm$ 2.2)	13.7 ($\pm$ 1.4)	15.7 ($\pm$ 2.6)	16.7 ($\pm$ 2.4)

Table 8: Results of the individual birds of the Identification task in Test 2 of Experiment 1, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Scr strong = strongly scrambled stimuli; Scr weak = weakly scrambled stimuli; Blur strong = strongly blurred stimuli; Blur weak = weakly blurred stimuli.

Original picture size		Identification Task			
		Transfer to			
Group	Subject	Scr strong	Scr weak	Blur strong	Blur weak
Intact	Casper	7	19	10	16
	Cordula	11	17	10	12
	Franz	10	20	13	17
	Hoopoe	13	17	14	16
	Solitaire	9	18	16	17
	Trisha	12	16	11	17
	Mean ($\pm$ SD)	10.3 ($\pm$ 2.2)	17 ($\pm$ 1.5)	12.3 ($\pm$ 2.4)	15.8 ($\pm$ 1.9)
Scrambled	Bobbison	12	17	11	11
	Gino	10	18	15	11
	Heinz	12	16	17	14
	Judith	15	14	12	15
	Lucy	12	15	12	13
	Yeti	10	15	11	15
	Mean ($\pm$ SD)	11. ($\pm$ 1.8)	15.8 ($\pm$ 1.5)	13.0 ($\pm$ 2.4)	13.2 ($\pm$ 1.8)
Blurred	Art	12	13	14	14
	Arthur	12	10	11	13
	Cindy	10	13	14	15
	Tino	6	11	16	12
	Vanessa	8	13	13	12
	Verena	12	9	14	13
	Mean ($\pm$ SD)	10.0 ($\pm$ 2.5)	11.5 ($\pm$ 1.8)	13.7 ($\pm$ 1.6)	13.2 ($\pm$ 1.2)

Table 9: Results of the individual birds of the Categorization task in Test 2 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Scr strong = strongly scrambled stimuli; Scr weak = weakly scrambled stimuli; Blur strong = strongly blurred stimuli; Blur weak = weakly blurred stimuli.

Small picture size		Categorization Task			
		Transfer to			
Group	Subject	Scr strong	Scr weak	Blur strong	Blur weak
Intact	Dr. House	14	17	16	17
	Mandy	15	13	18	17
	Mata Hari	17	16	17	17
	Mr. Speckle	12	11	12	16
	Snape	14	14	16	16
	Toby	12	17	13	18
	Mean ($\pm$ SD)	14.0 ($\pm$ 1.9)	14.7 ($\pm$ 2.4)	15.3 ($\pm$ 2.3)	16.8 ($\pm$ 0.8)
Scrambled	Claire	12	17	12	13
	George	12	17	17	17
	Harry	14	12	11	18
	Ida	14	19	12	17
	Lynn	11	16	10	17
	Penny	12	18	13	17
	Mean ($\pm$ SD)	12.6 ($\pm$ 1.3)	16.4 ($\pm$ 2.7)	12.6 ($\pm$ 2.7)	17.2 ($\pm$ 0.4)
Blurred	Emil	9	16	17	16
	Keira	14	10	16	18
	Klara	11	12	16	13
	Mag	15	14	17	17
	Martina	6	15	17	15
	William	12	14	19	18
	Mean ($\pm$ SD)	11.6 ($\pm$ 3.5)	13. ($\pm$ 2.0)	17.0 ($\pm$ 1.2)	16.2 ($\pm$ 2.2)

Table 10: Results of the individual birds of the Identification task in Test 2 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Scr strong = strongly scrambled stimuli; Scr weak = weakly scrambled stimuli; Blur strong = strongly blurred stimuli; Blur weak = weakly blurred stimuli.

Small picture size		Identification Task			
		Transfer to			
Group	Subject	Scr strong	Scr weak	Blur strong	Blur weak
Intact	Dr. House	10	18	16	18
	Mandy	6	13	15	18
	Mata Hari	15	15	15	16
	Mr. Speckle	10	16	17	16
	Snape	11	16	13	18
	Toby	14	18	15	18
	Mean ($\pm$ SD)	11.0 ($\pm$ 3.2)	16.0 ($\pm$ 1.9)	15.2 ($\pm$ 1.3)	17.3 ($\pm$ 1.0)
Scrambled	Claire	12	20	15	15
	George	14	17	16	16
	Harry	9	16	16	17
	Ida	11	18	13	15
	Lynn	16	19	16	18
	Penny	11	17	17	17
	Mean ($\pm$ SD)	12.2 ($\pm$ 2.5)	17.8 ($\pm$ 1.5)	15.5 ($\pm$ 1.4)	16.3 ($\pm$ 1.2)
Blurred	Emil	12	10	15	15
	Keira	12	15	17	14
	Klara	7	15	14	11
	Mag	12	15	12	16
	Martina	13	15	16	16
	William	10	13	16	19
	Mean ($\pm$ SD)	10.8 ($\pm$ 2.4)	14.6 ($\pm$ 0.9)	15.0 ($\pm$ 2.0)	15.2 ($\pm$ 2.9)

Table 11: Results of the individual birds of the Categorization task in Test 3 of Experiment 1, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int gray = grayscale intact stimuli; Scr gray = grayscale scrambled stimuli; Blur gray = grayscale blurred stimuli.

Original picture size		Categorization Task		
		Transfer to		
Group	Subject	Int gray	Scr gray	Blur gray
Intact	Casper	15	12	11
	Cordula	15	13	9
	Franz	14	15	13
	Hoopoe	13	14	12
	Solitaire	13	11	13
	Trisha	16	13	14
	Mean ($\pm$ SD)	14.3 ($\pm$ 1.2)	13.0 ($\pm$ 1.4)	12.0 ($\pm$ 1.8)
Scrambled	Bobbison	13	16	14
	Gino	11	12	11
	Heinz	17	16	13
	Judith	16	11	8
	Lucy	16	16	13
	Yeti	11	14	14
	Mean ($\pm$ SD)	14.0 ($\pm$ 2.7)	14.2 ($\pm$ 2.2)	12.2 ($\pm$ 2.3)
Blurred	Art	16	11	16
	Arthur	12	13	11
	Cindy	10	14	11
	Tino	13	12	16
	Vanessa	9	7	9
	Verena	11	6	9
	Mean ($\pm$ SD)	11.8 ($\pm$ 2.5)	10.5 ($\pm$ 3.3)	12.0 ($\pm$ 3.2)

Table 12: Results of the individual birds of the Identification task in Test 3 of Experiment 1, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int gray = grayscale intact stimuli; Scr gray = grayscale scrambled stimuli; Blur gray = grayscale blurred stimuli.

Original picture size		Identification Task		
		Transfer to		
Group	Subject	Int gray	Scr gray	Blur gray
Intact	Casper	15	12	11
	Cordula	15	13	9
	Franz	14	15	13
	Hoopoe	13	14	12
	Solitaire	13	11	13
	Trisha	16	13	14
	Mean ($\pm$ SD)	14.3 ($\pm$ 1.2)	13.0 ($\pm$ 1.4)	12.0 ($\pm$ 1.8)
Scrambled	Bobbison	13	16	14
	Gino	11	12	11
	Heinz	17	16	13
	Judith	16	11	8
	Lucy	16	16	13
	Yeti	11	14	14
	Mean ($\pm$ SD)	14.0 ($\pm$ 2.7)	14.2 ($\pm$ 2.2)	12.2 ($\pm$ 2.3)
Blurred	Art	16	11	16
	Arthur	12	13	11
	Cindy	10	14	11
	Tino	13	12	16
	Vanessa	9	7	9
	Verena	11	6	9
	Mean ($\pm$ SD)	11.8 ($\pm$ 2.5)	10.5 ($\pm$ 3.3)	12.0 ($\pm$ 3.2)

Table 13: Results of the individual birds of the Categorization task in Test 3 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int gray = grayscale intact stimuli; Scr gray = grayscale scrambled stimuli; Blur gray = grayscale blurred stimuli.

Small picture size		Categorization Task		
		Transfer to		
Group	Subject	Int gray	Scr gray	Blur gray
Intact	Dr. House	14	12	12
	Mandy	16	12	17
	Mata Hari	14	14	15
	Mr. Speckle	14	9	15
	Snape	12	14	11
	Toby	11	13	15
	Mean ($\pm$ SD)	13.5 ($\pm$ 1.8)	12.3 ($\pm$ 1.9)	14.2 ($\pm$ 2.2)
Scrambled	Claire	13	16	11
	George	14	16	15
	Harry	11	16	8
	Ida	12	13	10
	Lynn	10	8	11
	Penny	13	14	9
	Mean ($\pm$ SD)	12.0 ($\pm$ 1.6)	13.4 ($\pm$ 3.3)	10.6 ($\pm$ 2.7)
Blurred	Emil	15	12	14
	Keira	9	10	15
	Klara	9	9	14
	Mag	12	15	13
	Martina	13	12	17
	William	11	12	14
	Mean ($\pm$ SD)	10.8 ($\pm$ 1.8)	11.6 ($\pm$ 2.3)	14.6 ($\pm$ 1.5)

Table 14: Results of the individual birds of the Identification task in Test 3 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int gray = grayscale intact stimuli; Scr gray = grayscale scrambled stimuli; Blur gray = grayscale blurred stimuli.

Small picture size		Identification Task		
		Transfer to		
Group	Subject	Int gray	Scr gray	Blur gray
Intact	Dr. House	11	14	6
	Mandy	10	13	11
	Mata Hari	12	11	10
	Mr. Speckle	14	10	9
	Snape	10	12	8
	Toby	16	6	13
	Mean ($\pm$ SD)	12.2 ($\pm$ 2.4)	11.0 ($\pm$ 2.8)	9.5 ($\pm$ 2.4)
Scrambled	Claire	13	7	13
	George	13	12	12
	Harry	12	9	7
	Ida	12	13	10
	Lynn	13	10	11
	Penny	14	11	10
	Mean ($\pm$ SD)	12.8 ($\pm$ 0.8)	11.0 ($\pm$ 1.6)	10.0 ($\pm$ 1.9)
Blurred	Emil	8	5	9
	Keira	15	10	9
	Klara	8	13	9
	Mag	9	8	11
	Martina	14	11	10
	William	12	15	13
	Mean ($\pm$ SD)	11.6 ($\pm$ 3.0)	11.4 ($\pm$ 2.7)	10.4 ($\pm$ 1.7)

Table 15: Results of the individual birds in Test 4 of Experiment 1, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Blur and Scr = stimuli that were both blurred and scrambled.

Original picture size		Categorization Task	Identification Task
		Transfer to	Transfer to
Group	Subject	Blur and Scr	Blur and Scr
Intact	Casper	14	11
	Cordula	12	12
	Franz	9	15
	Hoopoe	11	14
	Solitaire	13	14
	Trisha	13	13
	Mean ($\pm$ SD)	12.0 ($\pm$ 1.8)	13.2 ($\pm$ 1.5)
Scrambled	Bobbison	16	15
	Gino	10	14
	Heinz	12	15
	Judith	13	14
	Lucy	15	16
	Yeti	10	14
	Mean ($\pm$ SD)	12.7 ($\pm$ 2.5)	14.7 ($\pm$ 0.8)
Blurred	Art	15	16
	Arthur	11	15
	Cindy	11	16
	Tino	9	14
	Vanessa	9	17
	Verena	14	15
	Mean ($\pm$ SD)	11.5 ($\pm$ 2.5)	15.5 ($\pm$ 1.0)

Table 16: Results of the individual birds in Test 4 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Blur and Scr = stimuli that were both blurred and scrambled.

Small picture size		Categorization Task	Identification Task
		Transfer to	Transfer to
Group	Subject	Blur and Scr	Blur and Scr
Intact	Dr. House	15	15
	Mandy	14	12
	Mata Hari	10	17
	Mr. Speckle	17	15
	Snape	17	15
	Toby	14	14
	Mean ($\pm$ SD)	14.5 ($\pm$ 2.6)	14.7 ($\pm$ 1.6)
Scrambled	Claire	18	17
	George	14	20
	Harry	14	14
	Ida	17	14
	Lynn	14	16
	Penny	16	16
	Mean ($\pm$ SD)	15.0 ($\pm$ 1.4)	16.0 ($\pm$ 2.4)
Blurred	Emil	13	13
	Keira	12	16
	Klara	13	13
	Mag	18	15
	Martina	12	14
	William	12	16
	Mean ($\pm$ SD)	13.4 ($\pm$ 2.6)	14.8 ($\pm$ 1.3)

Table 17: Results of the individual birds in Test 5 of Experiment 1, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int nov = novel intact stimuli; Scr nov = novel scrambled stimuli; Blur nov = novel blurred stimuli.

Original picture size		Categorization Task		
		Transfer to		
Group	Subject	Int nov	Scr nov	Blur nov
Intact	Casper	17	14	16
	Cordula	15	16	14
	Franz	19	19	9
	Hoopoe	20	17	15
	Solitaire	18	16	14
	Trisha	15	18	14
	Mean ($\pm$ SD)	17.3 ($\pm$ 2.1)	16.7 ($\pm$ 1.8)	13.7 ($\pm$ 2.4)
Scrambled	Bobbison	18	20	12
	Gino	19	16	11
	Heinz	13	16	13
	Judith	19	16	14
	Lucy	16	17	16
	Yeti	18	15	15
	Mean ($\pm$ SD)	17.2 ($\pm$ 2.3)	16.7 ($\pm$ 1.8)	13.5 ($\pm$ 1.9)
Blurred	Art	18	12	15
	Arthur	12	16	17
	Cindy	13	13	16
	Tino	16	17	18
	Vanessa	11	11	9
	Verena	15	12	18
	Mean ($\pm$ SD)	14.2 ($\pm$ 2.6)	13.5 ($\pm$ 2.4)	15.5 ($\pm$ 3.4)

Table 18: Results of the individual birds in Test 5 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int nov = novel intact stimuli; Scr nov = novel scrambled stimuli; Blur nov = novel blurred stimuli.

Small picture size		Categorization Task		
		Transfer to		
Group	Subject	Int nov	Scr nov	Blur nov
Intact	Dr. House	17	13	15
	Mandy	15	14	17
	Mata Hari	18	13	12
	Mr. Speckle	16	11	17
	Snape	17	17	15
	Toby	18	18	17
	Mean ($\pm$ SD)	16.8 ($\pm$ 1.2)	14.3 ($\pm$ 2.7)	15.5 ($\pm$ 2.0)
Scrambled	Claire	15	14	11
	George	16	17	17
	Harry	17	13	14
	Ida	17	13	15
	Lynn	19	17	15
	Penny	14	14	13
	Mean ($\pm$ SD)	16.6 ($\pm$ 1.8)	14.8 ($\pm$ 2.0)	14.8 ($\pm$ 1.5)
Blurred	Emil	15	14	18
	Keira	13	14	17
	Klara	16	12	17
	Mag	19	13	15
	Martina	16	13	18
	William	17	13	17
	Mean ($\pm$ SD)	16.2 ($\pm$ 2.2)	13.0 ($\pm$ 0.7)	16.8 ($\pm$ 1.1)

Table 19: Results of the individual birds of the Categorization in Test 6 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int large = original sized intact stimuli; Scr large = original sized scrambled stimuli; Blur large = original sized blurred stimuli.

Small picture size		Categorization Task		
		Transfer to		
Group	Subject	Int large	Scr large	Blur large
Intact	Dr. House	19	15	15
	Mandy	15	18	18
	Mata Hari	16	15	13
	Mr. Speckle	-	-	-
	Snape	17	16	6
	Toby	17	19	14
	Mean ($\pm$ SD)	16.8 ($\pm$ 1.5)	16.6 ($\pm$ 1.8)	13.2 ($\pm$ 4.4)
Scrambled	Claire	13	17	13
	George	17	16	17
	Harry	12	17	14
	Ida	20	18	14
	Lynn	17	16	13
	Penny	17	15	11
	Mean ($\pm$ SD)	16.0 ($\pm$ 3.0)	16.5 ($\pm$ 1.0)	13.7 ($\pm$ 2.0)
Blurred	Emil	18	14	18
	Keira	12	13	19
	Klara	12	10	12
	Mag	14	12	16
	Martina	13	16	18
	William	17	14	18
	Mean ($\pm$ SD)	14.3 ($\pm$ 2.6)	13.2 ($\pm$ 2.0)	16.8 ($\pm$ 2.6)

Table 20: Results of the individual birds of the Identification task in Test 6 of Experiment 2, shown as correct first choices for all groups and for both tasks. Significant results are given in bold. Int large = original sized intact stimuli; Scr large = original sized scrambled stimuli; Blur large = original sized blurred stimuli.

Small picture size		Identification Task		
		Transfer to		
Group	Subject	Int large	Scr large	Blur large
Intact	Dr. House	17	13	12
	Mandy	14	17	10
	Mata Hari	18	18	13
	Mr. Speckle	-	-	-
	Snape	17	17	16
	Toby	19	13	16
	Mean ($\pm$ SD)	17.0 ($\pm$ 2.2)	16.3 ($\pm$ 2.2)	13.8 ($\pm$ 2.9)
Scrambled	Claire	16	19	11
	George	16	18	10
	Harry	15	14	13
	Ida	17	17	13
	Lynn	14	17	15
	Penny	14	15	14
	Mean ($\pm$ SD)	15.3 ($\pm$ 1.2)	16.7 ($\pm$ 1.9)	12.7 ($\pm$ 1.9)
Blurred	Emil	14	11	13
	Keira	14	16	15
	Klara	14	14	16
	Mag	14	11	18
	Martina	16	11	13
	William	10	8	13
	Mean ($\pm$ SD)	13.7 ($\pm$ 2.0)	11.8 ($\pm$ 2.8)	14.7 ($\pm$ 2.1)

2. Group analyses

Table 21: Results of statistical analyses at group level in Experiment 1. Combined p-values ($\alpha \leq 0.5$) calculated by using Fisher's method are listed for all Groups and all tests. Significant results are given in bold.

Original picture size	Group	Transfer to	Categorization Task	Identification Task
Test 1: Other picture types	Intact	Scr	≤ 0.0001	≤ 0.0001
		Blur	0.0007	0.0648
	Scrambled	Int	≤ 0.0001	≤ 0.0001
		Blur	0.0104	0.0599
	Blurred	Int	0.1092	0.1093
		Scr	0.5671	0.0904
Test 2: Novel degrees	Intact	Scr strong	0.4888	0.5853
		Scr weak	≤ 0.0001	≤ 0.0001
		Blur strong	0.0007	0.0208
		Blur weak	≤ 0.0001	≤ 0.0001
	Scrambled	Scr strong	0.0397	0.1110
		Scr weak	≤ 0.0001	≤ 0.0001
		Blur strong	0.0006	0.0027
		Blur weak	0.0003	0.0042
	Blurred	Scr strong	0.4527	0.6455
		Scr weak	0.0011	0.2111
		Blur strong	≤ 0.0001	0.0009
		Blur weak	≤ 0.0001	0.0074
Test 3: Grayscale pictures	Intact	Int gray	≤ 0.0001	0.1241
		Scr gray	0.0104	0.1323
		Blur gray	0.0902	0.9926
	Scrambled	Int gray	≤ 0.0001	0.2775
		Scr gray	≤ 0.0001	0.5205
		Blur gray	0.0425	0.5062
	Blurred	Int gray	0.0583	0.2861
		Scr gray	0.2726	0.5493
		Blur gray	0.0137	0.4556

Original picture size	Group	Transfer to	Categorization Task	Identification Task
Test 4: Blurred & scrambled pictures	Intact	Blur&Scr	0.0902	0.0060
	Scrambled	Blur&Scr	0.0078	≤0.0001
	Blurred	Blur&Scr	0.1107	≤0.0001
Test 5: Novel pictures	Intact	Int nov	≤0.0001	
		Scr nov	≤0.0001	
		Blur nov	0.0004	
	Scrambled	Int nov	≤0.0001	
		Scr nov	≤0.0001	
		Blur nov	0.0012	
	Blurred	Int nov	≤0.0001	
		Scr nov	0.0005	
		Blur nov	≤0.0001	

Table 22: Results of statistical analyses at group level in Experiment 2. Combined p-values ($\alpha \leq 0.5$) calculated by using Fisher's method are listed for all Groups and all tests. Significant results are given in bold.

Small picture size	Group	Transfer to	Categorization Task	Identification Task
Test 1: Other picture types	Intact	Scr	≤0.0001	≤0.0001
		Blur	≤0.0001	≤0.0001
	Scrambled	Int	≤0.0001	≤0.0001
		Blur	0.0834	0.0027
	Blurred	Int	0.0379	0.0184
		Scr	0.1686	0.0850
Test 2: Novel degrees	Intact	Scr strong	0.0002	0.1352
		Scr weak	≤0.0001	≤0.0001
		Blur strong	≤0.0001	≤0.0001
		Blur weak	≤0.0001	≤0.0001
	Scrambled	Scr strong	0.0440	0.0270
		Scr weak	≤0.0001	≤0.0001
		Blur strong	0.0118	≤0.0001
		Blur weak	≤0.0001	≤0.0001

Small picture size	Group	Transfer to	Categorization Task	Identification Task
Test 2: Novel degrees	Blurred	Scr strong	0.0983	0.3328
		Scr weak	0.0009	0.0003
		Blur strong	≤0.0001	≤0.0001
		Blur weak	≤0.0001	≤0.0001
Test 3: Grayscale pictures	Intact	Int gray	0.0014	0.0311
		Scr gray	0.0427	0.2204
		Blur gray	≤0.0001	0.8009
	Scrambled	Int gray	0.1033	0.0246
		Scr gray	≤0.0001	0.5853
		Blur gray	0.1813	0.5434
	Blurred	Int gray	0.1316	0.1364
		Scr gray	0.1260	0.2447
		Blur gray	≤0.0001	0.7341
Test 4: Blurred & scrambled pictures	Intact	Blur&Scr	≤0.0001	≤0.0001
	Scrambled	Blur&Scr	≤0.0001	≤0.0001
	Blurred	Blur&Scr	0.0008	≤0.0001
Test 5: Novel pictures	Intact	Int nov	≤0.0001	
		Scr nov	≤0.0001	
		Blur nov	≤0.0001	
	Scrambled	Int nov	≤0.0001	
		Scr nov	≤0.0001	
		Blur nov	≤0.0001	
	Blurred	Int nov	≤0.0001	
		Scr nov	0.0096	
		Blur nov	≤0.0001	
Test 6: large pictures	Intact	Int large	≤0.0001	≤0.0001
		Scr large	≤0.0001	≤0.0001
		Blur large	≤0.0001	0.0016
	Scrambled	Int large	≤0.0001	≤0.0001
		Scr large	≤0.0001	≤0.0001
		Blur large	0.0005	0.0179
	Blurred	Int large	≤0.0001	0.0006
		Scr large	0.0032	0.0426
		Blur large	≤0.0001	≤0.0001

3. Stimuli

Training

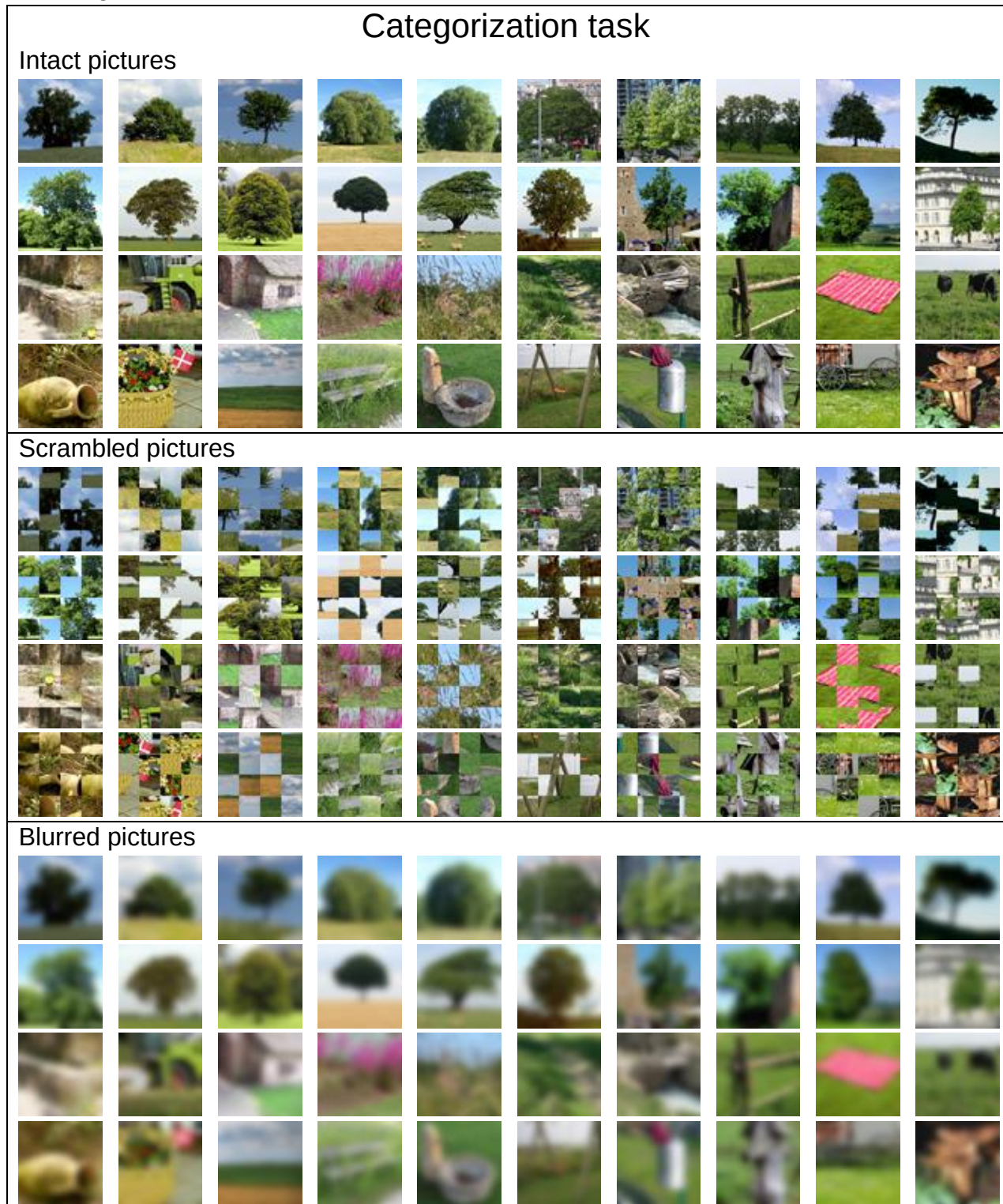


Figure 24: Full set of training stimuli of all groups, used in the Categorization task.

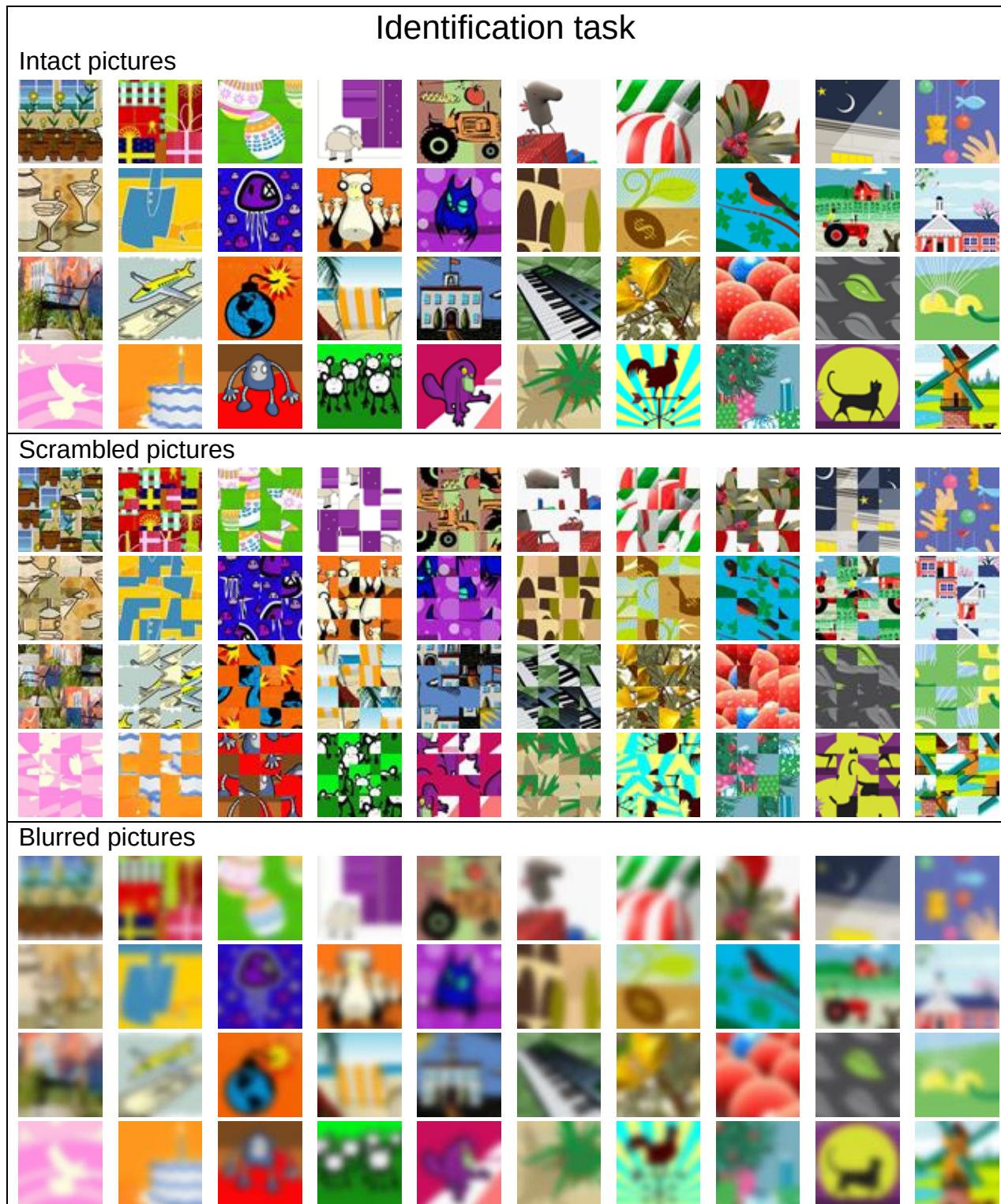


Figure 25: Full set of training stimuli of all groups, used in the Identification task.

Test 2

Categorization task

Strongly scrambled pictures

Weakly scrambled pictures

Strongly blurred pictures

Weakly blurred pictures



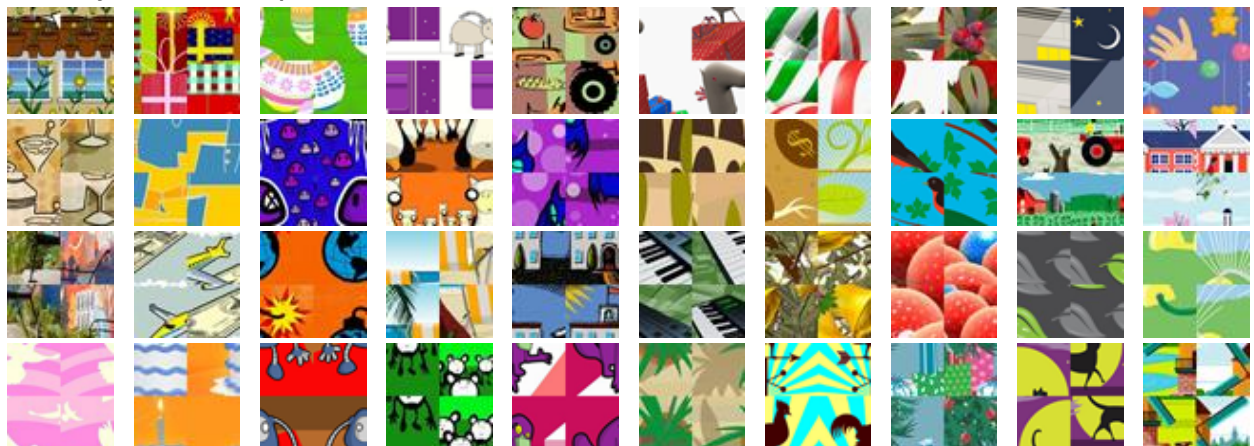
Figure 26: Full set of test stimuli used for all groups in the Categorization task of Test 2.

Identification task

Strongly scrambled pictures



Weakly scrambled pictures



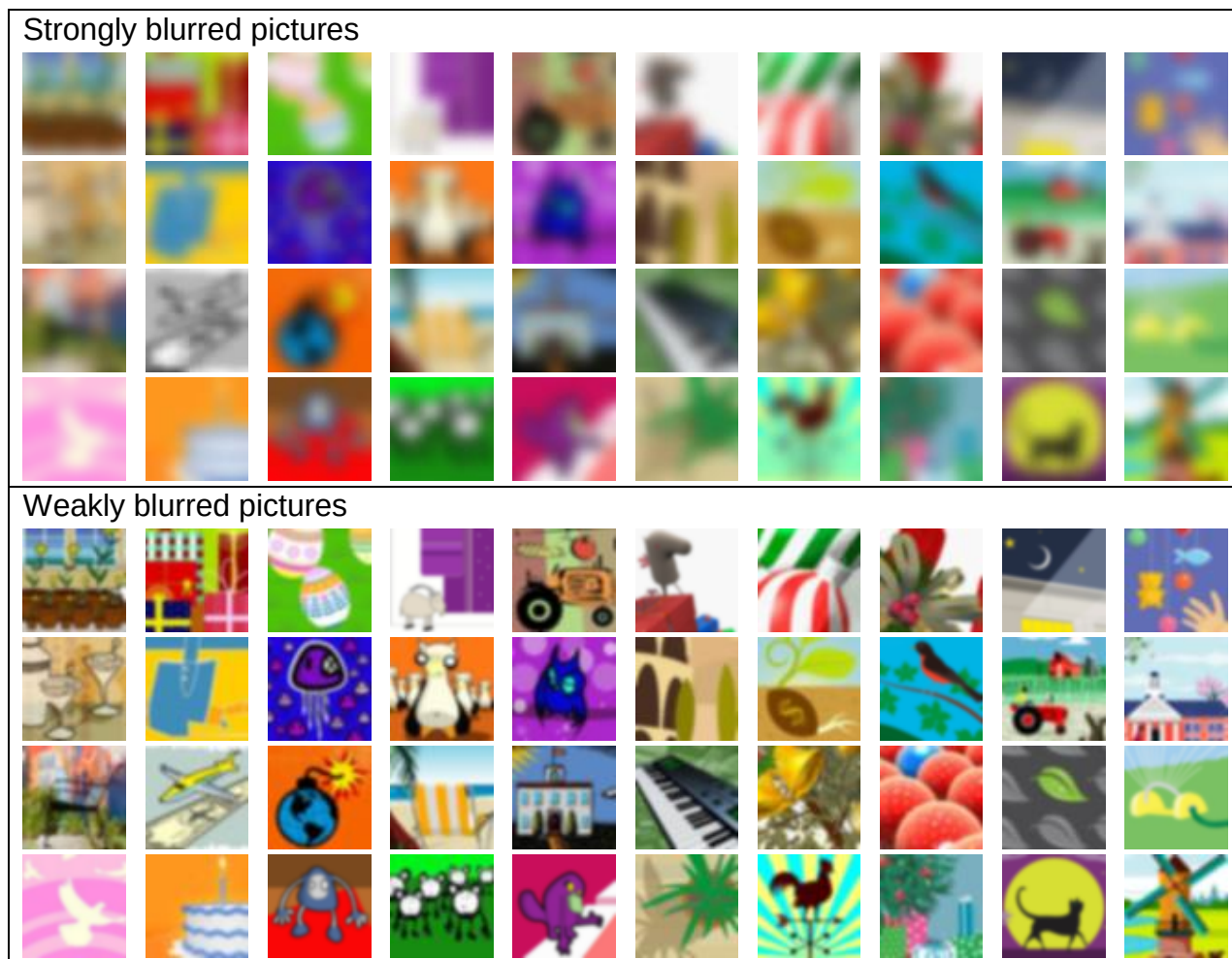


Figure 27: Full set of test stimuli used for all groups in the Identification task of Test 2

Test 3



Figure 28: Full set of test stimuli used for all groups in the Categorization task of Test 3.

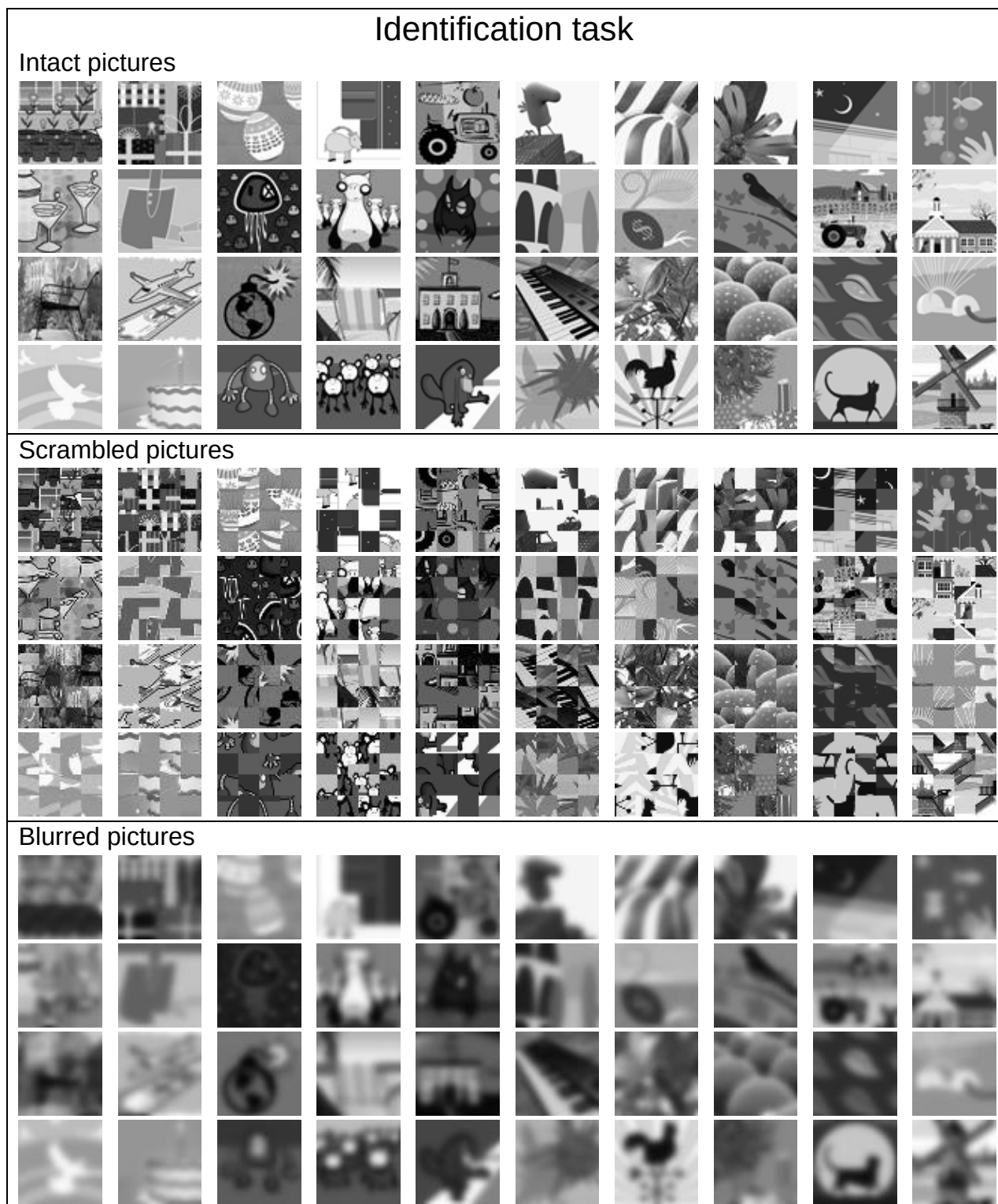


Figure 29: Full set of test stimuli used for all groups in the Identification task of Test 3.

Test 4

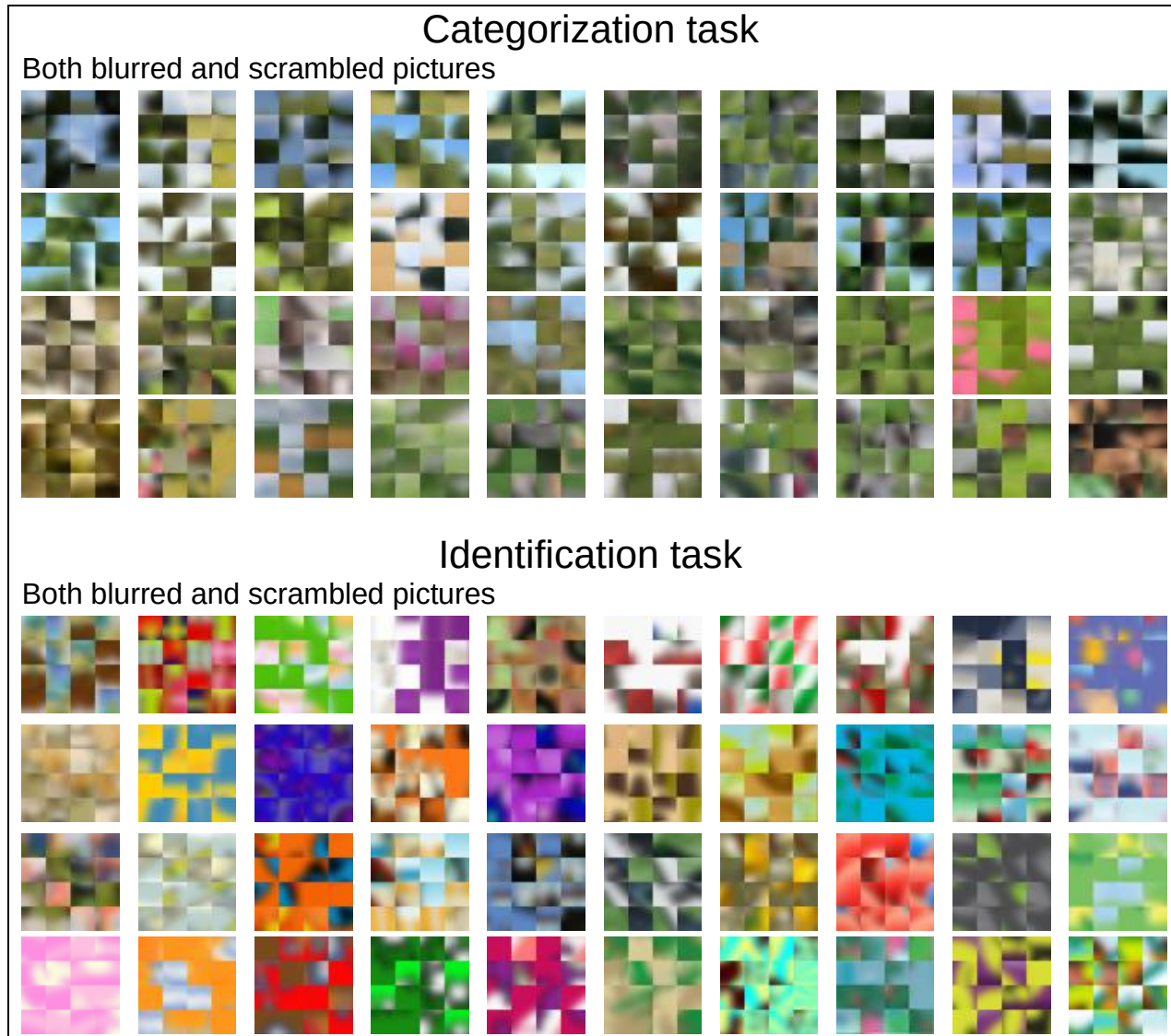


Figure 30: Full set of test stimuli used for all groups and both tasks of Test 4.

Test 5

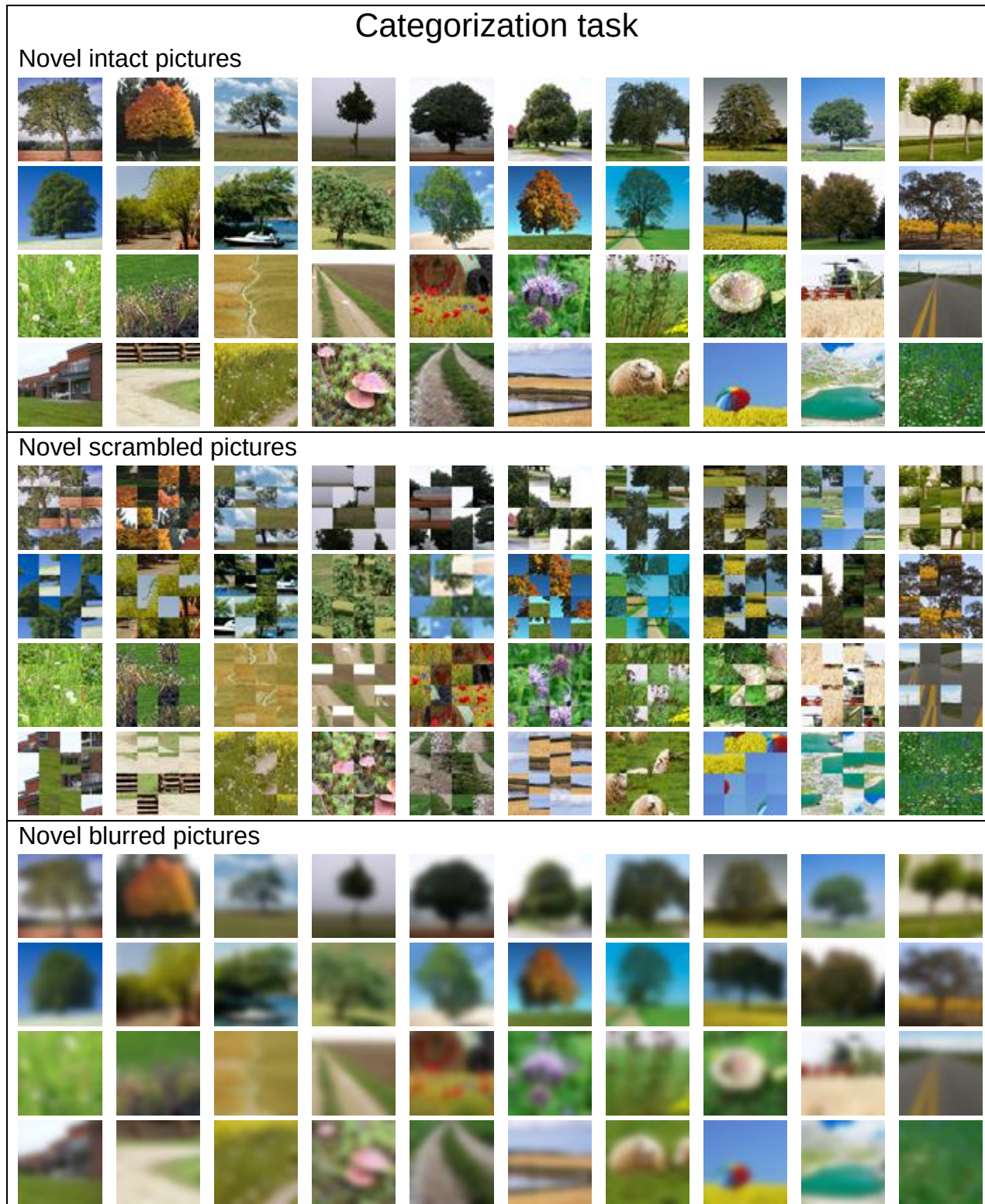


Figure 31: Full set of test stimuli used for all groups in the Categorization task of Test 5.

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SPRACHEN:

Englisch	Wort und Schrift
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