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„Influence of Familiarity with a Category on Picture-Object Recognition in Pigeons *(Columba livia)*“

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1 ABSTRACT

The ability to achieve representational insight in the sense that a subject is able to form associations between certain features of a real object and to transfer those associations to a picture of that object is cognitively quite demanding. So far, there is only little evidence for this ability in animals, which is, at least in part, due to a lack of appropriate testing methods. An innovative approach *(Complementary Information Procedure; CIP)* that allows for distinguishing between representational insight and less advanced mechanisms of picture-object recognition was recently introduced by Aust and Huber (2006). There, pigeons which were highly familiar with humans were trained to learn the discrimination between pictures of incomplete human figures (S+) and pictures showing something else (S-) and were then tested with parts of the human figures that were previously missing as well as with arbitrary patches of human skin. The results revealed that the subjects responded significantly more to the missing parts than to non-representative skin patches, which suggested that they recognized the missing parts as being parts of the human body. It was concluded that the pigeons were able of representational insight. It was argued that they could have done so only by means of associations between individual parts of humans, which were formed through experience with real persons and which could then be transferred also to pictures of humans.

The present study was carried out to further test this familiarity assumption. To this end, the experiment by Aust and Huber (2006) was replicated with pictures of an object class that was unfamiliar to the pigeons, namely snails. For this purpose, pigeons were required to learn the discrimination between pictures of incomplete snails (i.e., snails without shells or heads; S+) and pictures without snails (S-). Afterwards they were tested with the parts of the snails that were missing during training and with arbitrary patches of snail skin. In contrast to the study by Aust and Huber the subjects

showed no significant difference in responding to missing parts and to arbitrary skin patches, indicating that they recognized neither of them as belonging to the body of a snail and that they could not discriminate between true object parts and non-representative skin patches. It was concluded that this was due to the pigeons' lack of experience with real snails, which made it impossible for the birds to gain representational insight. Therefore, the results of the present study strengthen the assumption that experience with live instances of a category enables pigeons to recognize category members (and their parts) in pictures at a level beyond the discrimination of simple perceptual features, and are thus further (indirect) evidence of representational insight by this species. Furthermore, they confirm the CIP introduced by Aust and Huber as an appropriate method of investigating this ability.

2 INTRODUCTION

2.1 Pigeon Visual Categorization

Successful interactions with the enormous quantity of objects existing, both animate and inanimate, require an individual to detect, recognize and respond to objects in an appropriate manner (Spetch & Friedman, 2006). Thereby, the ability to assign objects to categories (e.g., on the basis of similarity) allows for notable reductions in cognitive demand by simplifying the complex and changing environment subjects are faced with (Zayan & Vauclair, 1998). "Similarity" may thereby be based on common perceptual features, on a common function, or on a logical relation between stimuli or classes (Herrnstein, 1990). In other words, categorization means to treat similar, but not identical things, as being equivalent by sorting them into the same category and by responding to them in the same or in a similar way (e.g., Herrnstein, 1984; Huber, 2001).

An early, influential demonstration of pigeons´ ability to sort stimuli was the pioneering study by Herrnstein and Loveland (1964), in which pigeons were trained to discriminate between photographs containing at least one human being and photographs without humans. If the presented picture contained a human, the pigeons were rewarded for pecking a key; if the picture did not contain a human, pecks were not rewarded. The pigeons readily learned the discrimination and also generalized to novel slides. All together, the birds succeeded in detecting human beings in photographs constituting "*a class of visual stimuli so diverse that it precludes simple characterization*" (Herrnstein & Loveland, 1964, p. 549).

Perceptual categories are often referred to as being "open-ended" as the number of possible class-members is potentially unlimited (Herrnstein, 1964). There is substantial evidence of pigeons´ ability to classify visual stimuli according to perceptual similarity (e.g., Aust & Huber, 2001; 2002; 2003; Cerella, 1979; Delius, 1992; Huber, 2001; Huber et al., 2000; Huber & Aust, 2006; Lazareva et al., 2004; 2006; Yamazaki et al., 2007). These as well as many other studies showed that pigeons were not only able to discriminate between different categories but that they could also generalize a learned discrimination to novel class members. These demonstrations also revealed that learning about and forming a perceptual category, respectively, was not restricted to stimuli which the pigeons were likely to be familiar with, i.e., stimuli from their natural environment, but that this ability also extended to stimuli that the pigeons had most probably never seen before in their lives, like underwater pictures of fish (Herrnstein & de Villiers, 1980).

2.2 Picture-Object Recognition

2.2.1 The Problem of Picture-Object Recognition

One of the basic issues relating to the study of both human and animal visual cognition concerns the use of symbolic instead of real objects, like pictures, maps or scale models. Pictures in particular have become one of the most favored types of experimental stimuli. Compared to more simple artificial stimuli, like geometrical forms, pictures share many characteristics with the real objects they depict. Therefore, they are ecologically more valid. There are many studies in which the experimenters made use of pictorial stimuli such as colored slides or photographs on the assumption that the animal makes some link between them and the real-world stimulus that is represented (e.g., Candland, 1969; Bruce, 1982; Brown and Dooling, 1992). However, successful categorization does not necessarily mean that a subject also understands what a pictorial stimulus actually represents. The question is, whether animals, just like humans, can recognize the relation between 2D-pictures and their 3D-referents. Are non-human animals capable of picture-object recognition in this way?

Even in humans, the recognition of photographs or pictures is not as obvious as one might think (Slater et al., 1984; Tomasello, 1999; Tomasello et al., 1997; Bovet & Vauclair, 2000). In cross-cultural studies it has been shown that people who had never seen two-dimensional representations had difficulties recognizing pictures (Miller, 1973). In fact, they needed some exposition to and experience with them before they were capable of perceiving what they showed (Deregowski, 1989; Miller, 1973).

Regarding pigeons, one has to keep in mind that they have huge visual memory capacities (Cook et al., 2005; Fagot & Cook, 2006; Vaughan and Greene, 1984; von Fersen & Delius, 1989). As they are able to store large numbers of visual images they may have solved by rote learning at least some of the tasks that had initially been interpreted in terms of representational insight. Alternatively, they may have formed categories by extracting an array of category-defining features and combining them into a perceptual class rule. Indeed, both mechanisms (rote learning and learning of a perceptual class rule) may allow for generalization to novel instances of a learnt category without recognition of the link between a photograph and the real world being required (Lea, 1984).

Generally, it has to be considered that pictures are always abstractions, i.e., simplifications, of the real objects they portray. In other words, they always entail a reduction in the informational content compared to the real object (Bovet & Vauclair, 2000). They fail to display various properties that facilitate or even make possible the recognition of real things, like 3D-cues, motion, auditory and olfactory cues (Bovet & Vauclair, 2000; Delius et al., 2000; Fagot et al., 2000). Furthermore, pictorial stimuli are always reduced along physical dimensions, such as size (most of the time), color and stereoscopic as well as motion parallax cues that are necessary for perceiving depth (Bovet & Vauclair, 2000). Also, pictures misrepresent the real world due to technical shortcomings, for instance poor luminous and chromatic replication, flicker etc. (Bovet &

Vauclair, 2000; Delius et al., 2000). Finally, pictures (both photographs and stimuli presented on computer screens) are usually adapted to human vision. As a result, they often lack some critical features of the vision of other species (e.g., UV-light for birds) and therefore offer false color representations. In contrast to the trichromatic visual system of humans, pigeons are capable of tetrachromatic or even pentachromatic vision. Therefore, they are able to distinguish color qualities that humans are not able to detect (Delius, 2000). As a consequence of all these factors, pictures may appear quite differently to a pigeon from real objects. It is very important to be aware that we can´t tell what a nonhuman subject actually perceives when it looks at a picture, and we can't take for granted that it will comprehend what a picture actually shows.

2.2.2 Levels of Picture-Object Recognition

There are different stages regarding the mechanisms by which an animal may recognize the relation between an object and its picture, i.e., establish picture-object correspondence.

(1) Perceptual level. The first and cognitively least demanding level is that of recognizing the perceptual properties of an object, i.e., the subject simply needs to discriminate one or more visual features on the picture and recognize them in the real object (or vice versa). Positive transfer is thereby mediated by simple invariant 2D-characteristics, which are visible in both the picture and the object. Therefore, transfer does not necessarily mean that the subject recognized the 2D-picture as equivalent to the real 3D-object. A characteristic patch, visible in both an object and its picture, may, for example, be sufficient for recognition without any comprehension of the pictures´ representational nature.

(2) Associative level. At the next level there is the ability to recognize the associations between certain features (or parts) of an object and to transfer these associations to pictures of that object (or vice versa). This would still not imply that a subject understands the pictures´ representational nature in the strictest

sense, but would go beyond simple discrimination of individual 2D-features. Through my thesis I will use the term "representational insight" in this sense.

(3) Abstract level. The most abstract and cognitively most demanding level is that of "true" representational insight. This is the ability to understand that pictures are entities that "stand for something other than themselves" (DeLoache, 1995; 2000), i.e., to evaluate them as representations of the real world. This requires achieving a dual representation, as pictures have a concrete as well as an abstract nature. It is thus necessary to represent them as real entities and at the same time, represent their abstract relation to their referents (DeLoache, 2000; Ittelson, 1996). At the same time, a subject must not confuse the picture with the real object (Parron et al., 2008) as this would mean that the object and the picture are processed in exactly the same way, with no distinction between the two being made. The picture would then be recognized as being the same as the object (Fagot, 1999). True representational insight, by contrast, requires a subject to be aware of the fact that the picture is different from the real object. It has to understand that the picture is a representation of the object but not the object itself. In this case, the processing of the picture is independent of the processing of the actual object (Fagot, 1999). Representational insight in its strictest sense is therefore the most advanced mechanism of establishing picture-object correspondence.

2.2.3 Methods of Investigating Picture-Object Recognition

The question of picture-object recognition is usually addressed by means of two main types of approaches. One approach is to test if an animal shows *adapted behaviour* to pictorial representations of 3D-objects. This could, for example, be social behaviour towards pictures of conspecifics (e.g., Shimizu, 1998), fear in the presence of threatening stimuli (e.g., Vandenheede & Bouissou, 1995), or predator behaviour with pictures of prey (e.g., Clark & Uetz, 1990). However, such behaviour could also be elicited by simple 2D-features common to the picture and the real object, i.e., successful generalization does not necessarily require the ability to recognize the correspondence between a picture and its object (Spetch & Friedmann, 2006). Also, display of adapted behaviour does not rule out the possibility of picture-object confusion.

The other approach to examine picture-object recognition is that of testing for *transfer of discrimination from real objects to pictures*, or vice versa (e.g., Bovet & Vauclair, 1998; Cabe, 1976; Delius, 1992; Savage-Rumbaugh et al., 1980; Spetch & Friedmann, 2006; Truppa et al., 2009; Watanabe, 1993, 1997a). This means that an animal is trained to discriminate between real objects and is then tested with pictures of those objects, or it is trained to discriminate between pictures of objects and is then tested with their real 3D-referents. Very rarely, however, have such experiments allowed defining the cognitive strategy by which transfer was accomplished (Aust & Huber, 2006). In most studies mentioned until now, the presented pictures contained some of the same perceptual features as the real objects they portrayed. Thus, it was almost impossible to tell how and at which cognitive level the pictures were processed. In particular, it could not be decided whether transfer occurred on a merely perceptual basis due to the recognition of some invariant 2D-features, at the associative level due to transfer of learned associations, or at the most abstract level, due to true representational insight. Until now, there are only a few studies that really tried to overcome the problem of common perceptual features in objects and pictures.

One example is provided by Watanabe (1997a), who trained pigeons on two discrimination tasks. Stimuli were edible and inedible objects as well as pictures of them. One group of pigeons had to discriminate between real objects and their photographs (regardless whether the stimuli were edible or not), i.e., they had to sort them into a “real object” and a “photograph” category. The other group had to discriminate between edible and inedible items (regardless whether the stimuli were real objects or pictures), i.e., they had to sort the stimuli into the categories “edible” and “inedible”. The pigeons of both groups learned the discrimination and also showed transfer to novel stimuli. The author suggested that these results demonstrated that the pigeons were able to classify the stimuli according to the category rule “edible/inedible”, but were also able to distinguish between real objects and pictures. Therefore, he concluded that pigeons can recognize pictures as representations of real objects.

Another experiment was conducted by Dasser (1987) who found that long-tailed macaques recognized the identity of group members presented on color slides. After training on few examples, the subjects correctly identified novel views of the animals shown in training. It was suggested that slides of group members could be used as representations of monkeys individually known to the subjects.

A more recent study was carried out by Aust and Huber in 2006, in which they introduced an approach called *Complementary Information Procedure (CIP)*. This procedure is different from other testing procedures in the sense that it actually allows for disentangling the role of perceptual and cognitive factors. In this case, the possibility of stimulus generalization by means of simple perceptual features is widely ruled out. The subjects are first trained to discriminate between pictures that show a particular incomplete target object (S+) and pictures that show something else (S-). Once the subjects have learned the discrimination they are tested with three novel types of pictures. The first type shows a part of the picture that has been present in the training stimuli (seen part; SP), to see if the subjects are basically able to recognize isolated parts of the objects. The pictures of the second type show the previously missing part (unseen part; UP). As the training and the UP test stimuli do not include the same parts of the target objects, but instead provide complementary information, transfer cannot be based on the recognition of simple item-specific perceptual features present in both training and test stimuli (e.g., salient shapes or patches of characteristic texture). To control for transfer by means of category-specific features the subjects are also tested with a third type of pictures showing “non-parts”, which are patches of arbitrary shape and size that contain similar surface properties as “true” parts. Poorer transfer to non-parts than to true complementary parts would indicate an ability to perceive the correspondence between pictures and their 3D-referents at a level beyond the recognition of some simple category-specific features (Aust & Huber, 2006).

Aust and Huber (2006) trained two groups of pigeons to discriminate between pictures of incomplete human figures (Class P) and pictures that were devoid of humans (Class NP). All birds were highly familiar with humans as they saw keepers, experimenters, students and/or visitors almost every day. The pigeons were divided into two groups: Group No Hands, in which the humans on the pictures were devoid of hands and Group No Head, in which the depicted humans were devoid of heads. After successful discrimination the pigeons were tested with SP stimuli, i.e., heads for Group No Hands and hands for Group No Head, UP stimuli, i.e., hands for Group No Hands and heads for Group No Head and skin stimuli (SK), i.e., patches of human skin of arbitrary size and shape.

Most importantly, the pigeons responded significantly less to the non-representative skin stimuli (SK) than to the true complementary parts (UP), while peck rates on SP and UP stimuli did not differ significantly from each other. The authors concluded that the pigeons recognized the true missing parts but not the skin patches as belonging to the human figure. Thereby, the birds must have drawn on their experience with real humans and their parts because they had never seen any 2D-representations of the unseen parts during training but could nevertheless classify them as belonging to Class P. It was concluded that the pigeons must have recognized the correspondence between the (incomplete) human figures depicted in the training stimuli and live human beings (and between pictures of the missing parts and real body parts). In summary, the authors claimed that the pigeons had not relied on any simple

2D-features present in both training and test stimuli but that responding had mainly been based on representational insight and that perceptual features, like the skin color, played an accessory role at best (see also Aust & Huber, in press).

Nevertheless, the authors acknowledged that transfer could have been achieved through learning about the associations of the individual parts of an object through real-life experience which were then recognized in pictures of this object. In other words, transfer was accomplished by a mechanism beyond simple feature discrimination, but the pigeons may not necessarily have fully understood the representational nature of the pictures. Thus, the CIP cannot distinguish between the associative level and the most abstract level of representational insight in its strictest sense, but is an appropriate tool for disentangling these two from simple feature discrimination.

In a follow-up study Aust and Huber (2010) replicated their experiment with pigeons that had extensive experience with live human beings ("Unrestricted" pigeons) as well as with pigeons that had never seen human heads ("Restricted" pigeons). Half of the birds of each condition were assigned to Group No Hands, the others were assigned to Group No Head. The rationale was that if the pigeons simply relied on spurious perceptual features in the pictures, there should be no difference in the responses between "Restricted" and "Unrestricted" pigeons. If however, the pigeons were capable of representational insight the birds of Group Restricted No Head, which had no visual pre-experience with real-life referents of the "unseen parts", should be unable to perceive the UP stimuli as representations of real body parts. Thus, these would be the only pigeons that should fail to prefer UP over SK stimuli, while the three other groups should do so (Groups Unrestricted No Hands; Unrestricted No Head; Restricted No Hands). Indeed, the results showed that the birds of Group Restricted No Head did not respond differently to UP and to SK stimuli, as was the case in all other groups. Therefore, the authors suggested that the successful groups could solve the task because of their experience with live hands and heads, respectively, whereas this was impossible for Group Restricted No Head, as these birds had never seen any real human heads before. In summary, this study confirmed the conclusions of the previous one (Aust & Huber, 2006), namely, that pigeons can recognize the relation between pictures and their referents not just by means of simple perceptual features presented in both an object and its picture, but that they can indeed base their responding on representational insight (at least at the associative level). In particular, the second study complemented the first in demonstrating the crucial role of experience with real-life representatives of a category as a prerequisite for understanding the correspondence between pictures and objects.

These findings are in line with the results of earlier studies that illustrated the importance of experience for picture-object recognition. One example was provided by Watanabe (1997b). He trained two groups of pigeons in a discrimination task to peck on a TV screen when a feeder or a coffee mug, respectively, appeared. The feeder was considered to be a "familiar object" whereas the mug was an "unfamiliar object". After training, the pigeons were tested with images of unusual views of those objects. Pigeons trained with the "familiar object" showed generalization to the new views, whereas pigeons trained with the "unfamiliar object" failed to solve the task. The author concluded that experience with real objects, as it was the case for the feeder, facilitated object-picture recognition.

Truppa et al. (2008) found similar results in the tufted capuchin monkeys. The monkeys were first trained to discriminate 3D-objects and then tested if they could match the objects with their color photographs. Then they were trained to discriminate color photographs of new 3D-objects and were subsequently tested for their ability to match these with the real objects. The monkeys were able to match familiar objects with their color photographs, but showed poorer performance in the Picture-to-Object Test. It was concluded that the acquired familiarity with the real objects in the first part of the experiment may have facilitated object-to-picture transfer during testing, whereas the lack of previous visual exposure to the real objects in the second part might have impeded picture-to-object transfer. This suggests that familiarity with real objects plays an important role in the ability to associate them with pictures thereof.

2.3 Aim of the Study

My study investigated whether pigeons would behave differently if trained and tested in the same way as the ones in Aust and Huber (2006), but with pictures of a category that they had no prior experience with. If, indeed, the pigeons in the "human"-study responded differently to UP and SK stimuli because of their experience with live humans (i.e., representational insight), no differences in peck rates between unseen parts and non-representative stimuli should occur in an experiment where real-life experience is missing, as neither type would be recognized as being representative. In other words, pigeons trained on pictures of objects of an unfamiliar category should fail to classify "true" complementary parts (UP) as class members and should not respond differently to UP stimuli and arbitrary, non-representative stimuli — just like it was the case for the pigeons in Group Restricted No Head in Aust and Huber (2010). If, however, the pigeons responded more to the unseen parts than to arbitrary patches, just like the birds in Aust and Huber (2006), this would question any conclusions in terms of representational insight that were made in that previous study. Instead, other mechanisms of responding, like, e.g., strategies based on perceptual feature detection, would then have to be considered. Alternatively, similar outcomes in the two studies may indicate that the results obtained by Aust and Huber were an artifact of some methodological flaws. Hence, a secondary aim of my study was to check if the

Complementary Information Procedure (CIP) is indeed a reliable method to investigate picture-object recognition in pigeons.

Choosing a category unknown to the pigeons needed some considerations, as category members should fulfill some major criteria. First, they should bear some reasonable degree of overall perceptual similarity to each other; second, they should possess well-distinguishable parts, such as “heads”, and third, they should not bear strong similarities with members of familiar categories in order to reduce transfer by between-category generalization. I eventually decided to use “snails” as the category to be tested, as this seemed to fulfill all these criteria. I used the same design and stimulus generation techniques as Aust and Huber (2006), which allowed maximum comparability of the results and also provided a straightforward way to control for any artifacts that may have contributed to the results of Aust and Huber (2006).

3 METHODS

3.1 Subjects and Housing

Eight adult pigeons (*Columba livia*) were used in this experiment. Seven of them were homing pigeons, one was of a local Austrian race, called *Strasser*. The birds were housed in four outdoor aviary compartments (each measuring 3 m x 1.1 m x 3 m), together with 10-14 conspecifics of mixed sex and breed. Five of the homing pigeons lived together in Aviary 1 (Cordula, Franz, Josef, Klara and Herbert), one lived in Aviary 4 (Bobbison) and one in Aviary 6 (Daisy). The Strasser pigeon (Verena) lived in Aviary 5.

Five pigeons had several years of experience with visual discrimination tasks at the onset of the experiment, but they were all naive to the present task. For three pigeons (Bobbison, Daisy and Verena) it was the first time they participated in a visual discrimination task. For this reason they had to get familiarized with the experimental set-up and the procedure prior to the experiment.

On testing days, subjects were fed a small amount of food (mixed grain) after experimental sessions in addition to the food they got as a reward during testing. On nontesting days, the pigeons were supplied with extra rations of mixed grain. Water and grit were freely available in the aviaries at any time.

3.2 Apparatus

The pigeons were trained and tested in wooden experimental chambers ("Skinner-boxes"; see Figure 1) which they entered from their respective outdoor compartments through a connecting channel. This special housing technique was introduced by Huber (1994). The interior size of the boxes was 50 x 30 x 40 cm. The frontal wall of the chamber was constituted by a 15.0" XGA Color TFT-LCD monitor (resolution = 1024 x 768 pixels) mounted behind an infrared touchframe (CarrollTouch by Elo). In front of the screen there was an “intelligence panel” with a clear perspex pecking key in its center. Stimuli were presented on the LCD monitor, at a distance of 5 cm behind the pecking key. Food reward was administered by means of a special feeder, the “grain lifter”. It consisted of an electric motor that lifted a piston with a depression on top up through a food reservoir. Thereby, grain was accumulated in the depression. The piston was then lifted through a hole in the bottom of the testing chamber and the grain became accessible to the pigeon directly below the touchscreen. A hopper light illuminated the top of the piston whenever grain was accessible. Data acquisition and device control were handled with hard- and software especially developed for the requirements of learning experiments with animals, especially pigeons. The presentation computer (Embedded CLab E2, © M. Steurer) incorporated a personal computer that ran the experimental software (CognitionLabLight, © M. Steurer), the device electronics, and the power supply for controlling the feeder motor. All boxes were equipped with a video surveillance system so that the birds’ activities could be observed on a control screen. Furthermore, a Virtual Network Computing server (VNC) was installed on every presentation computer. VNC is a graphical desktop sharing system that allows to remotely control other computers. This enabled me to track the experimental sessions on the control monitor via VNC client.

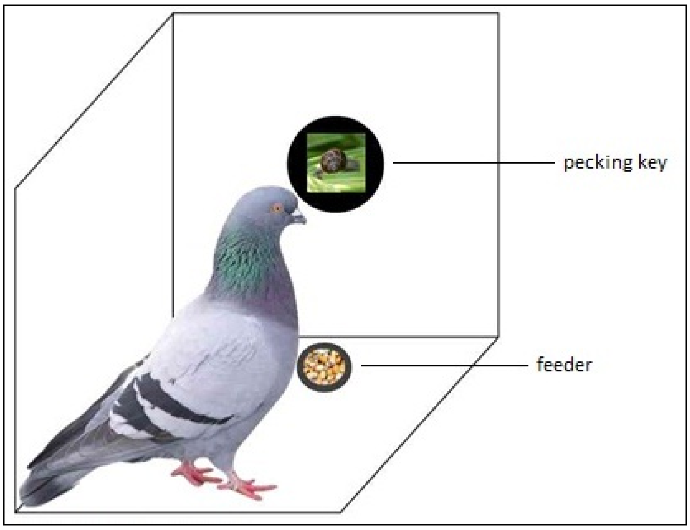

Figure 1. Experimental chamber including the pecking key and the feeder outlet. On positive trials, responses to the pecking key activate the feeder and the pigeon is allowed to feed for a pre-specified time period.

3.3 Stimuli

The stimuli were color photographs taken from different online databases (http://www.photodisc.com, http://www.freedigitalphotos.net, http://bayimages.net, http://www.acclaimimages.com). Positive pictures (S+) showed one or more snails (Class Snails, S), negative pictures (S-) showed something else (Class No Snails, NS). Examples of the training stimuli are shown in Figure 2 (see also Appendix, Figures A1-A3). It is worth noting that the backgrounds of the pictures were similar in both classes (i.e., also the pictures of Class NS showed sceneries where snails were likely to occur). Furthermore, I also ensured that positive and negative stimuli included similar colors and shapes in order to prevent the subjects from using a learning strategy based on memorization of conspicuous spurious background features or particular colors. The subjects were arbitrarily assigned to either of two experimental groups, each consisting of 4 birds (see Table 1).

Table 1. Subjects and assignment to groups

Group No Shell	Group No Head
Bobbison	Cordula
Josef	Daisy
Klara	Franz
Verena	Herbert

For Group No Shell, the training stimuli shown in Class S were devoid of the snail´s shell. Hence, only the body of the snail (including the head) was shown. In Group No Head, the training stimuli shown in Class S were devoid of the snail´s head. Hence, only the headless body and the shell were shown. The photographs were adapted to the demands of the present task in Photoshop 7.0. I created the stimuli of Class S by digitally removing the critical part or by choosing cutouts that did not include the respective snail part. Also the stimuli of Class NS were digitally manipulated, e.g., by removing or covering parts of depicted (non-snail) figures or objects in order to prevent any artifacts possibly brought in by such manipulations from occurring in just one class.

Figure 2. Examples of the training stimuli for both groups. a) Examples of S+ stimuli of Group No Head; b) Examples of S+ stimuli of Group No Shell; c) Examples of S- stimuli, which were the same for both groups.

I left the backgrounds unchanged in both classes to keep the stimuli as natural as possible and to provide maximum comparability with the study of Aust and Huber (2006). The stimuli were presented at a size of 128 x 128 pixels and a resolution of 72 dpi, thus producing a 45 x 45 mm picture on the screen.

The pictures for the subsequent Generalization Test, derived from novel images, were created in the same way as the training stimuli (see Appendix, Figures A4-A6). The test stimuli for the critical Picture-Object Recognition Test, again made from novel pictures, showed just isolated parts of snails, namely heads, shells, or arbitrary patches of snail skin. These, as well, were created by digitally removing any undesired snail parts or by choosing pictures that *a priori* contained the required parts (e.g., pictures showing just a snail shell). Regarding the skin stimuli, half of those pictures were created by digitally removing the house and other parts of the snail skin until just an appropriate part of skin remained, the other half by pasting cutouts of a novel Class S picture onto a novel Class NS picture. Examples of the test stimuli are shown in Figure 3 (see also Appendix, Figures A7-A9).

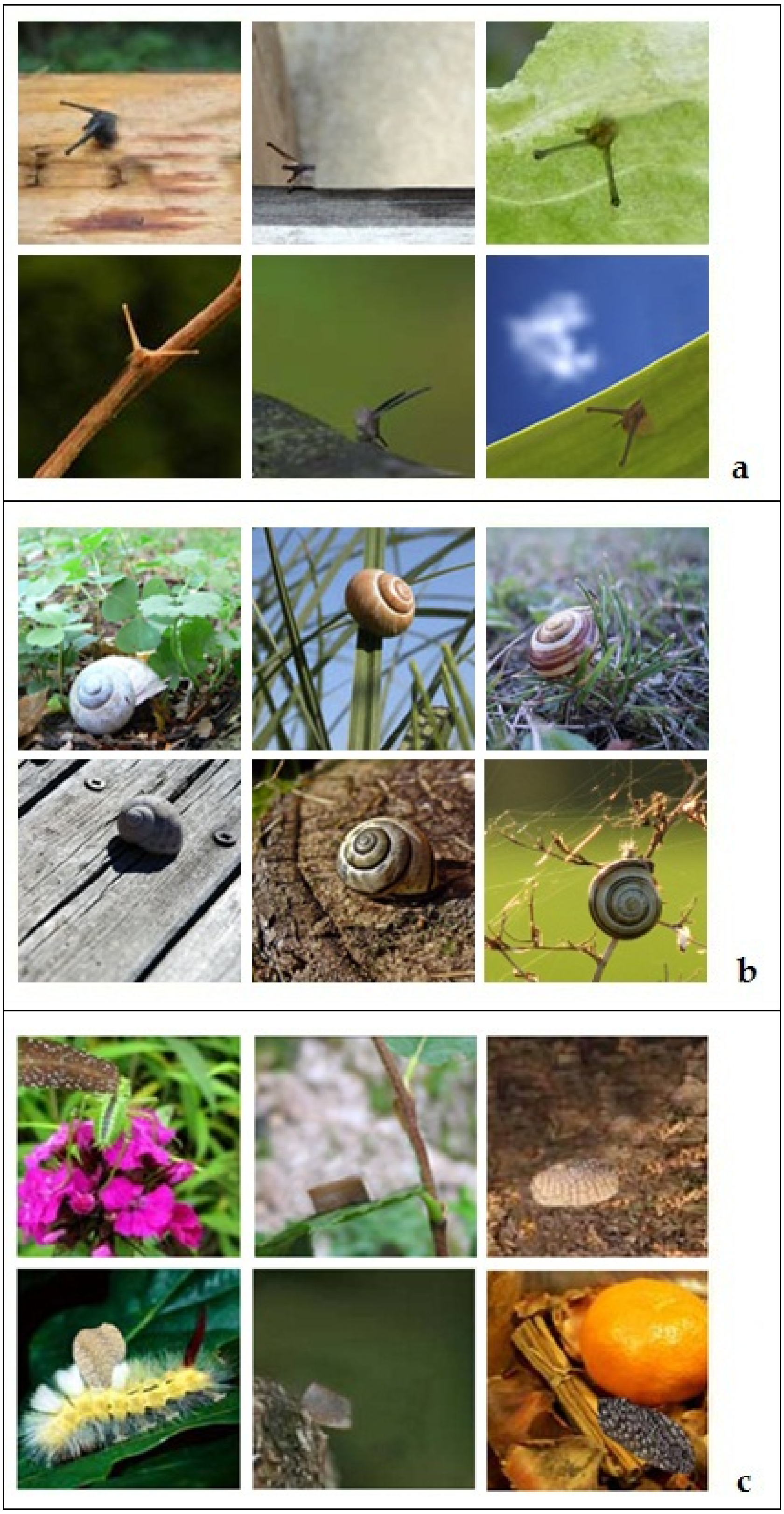

Figure 3. Examples of the test stimuli. a) Heads, which were seen parts for Group No Shell and unseen parts for Group No Head. b) Shells, which were seen parts for Group No Head and unseen parts for Group No Shell. c) Skin patches, which were the same for both groups.

3.4 Procedure

The procedure was a standard Go/NoGo-Procedure. A schematic overview of the Go/NoGo-Procedure is shown in Figure 4. The pigeons were required to peck in the presence of a positive stimulus and to refrain from pecking in the presence of a negative stimulus. Pecks were counted throughout stimulus presentation, but only pecks emitted during the first 10 s of a trial (fixed interval, FI) entered analysis later. During the subsequent variable interval (VI, range 1-20 s), it was unimportant whether the pigeons pecked, as the function of this was just to prevent the emergence of time patterns. After the VI was completed, the decision phase followed. There, the subjects had to respond three times within three seconds to receive food reinforcement in positive (GO) trials. In negative (NOGO) trials, the subjects had to refrain from responding during the decision phase, with each response prolonging stimulus presentation. Negative trials were terminated only after no responses had occurred within 8 s. No food was delivered on negative trials. The image remained visible throughout the entire trial. Each trial was followed by an intertrial interval (ITI), a dark phase of 3 s that signaled the forthcoming stimulus presentation. Test stimuli were presented with neutral contingencies, which means that the respective test trial resulted in neither food access nor a delay interval but was terminated after the first 10 s of presentation.

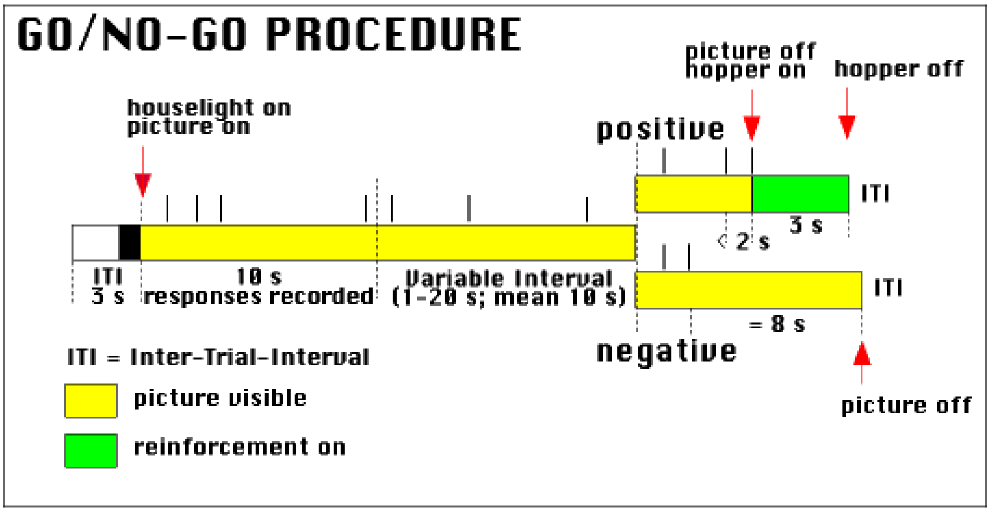

Figure 4. Schematic depiction of the Go/NoGo-Procedure (retrieved from http://www.pigeon.psy.tufts.edu/avc/print/huber/huber_figprint.htm; Huber, 2001; note that in my experiment there was a grain lifter instead of the hopper). The figure shows the individual phases of one trial. Important events are indicated by red arrows. The time during which a stimulus is present is marked yellow; the time during which food is available is marked green. Pecks are indicated by vertical lines above the time line. (In this example, four pecks would have been recorded in the first 10 seconds of presentation.)

Each bird accomplished one session a day, 5 days a week, with each session consisting of the presentation of 40 stimuli, 20 positive (Class S) and 20 negative ones (Class NS). The sequences were presented quasi-randomly, which means that they never contained more than 3 positive or negative stimuli in immediate succession, and that the first stimulus of each session was always a positive one.

At the onset of each session a so-called starter stimulus (a colored square) was presented. The same starter stimulus was used for the pre-training and for the experimental phase. The starter stimulus was introduced in order to make sure that the subject was attentive to the task, no matter if the first stimulus of a session was positive or negative. (The latter could happen if a session had to be aborted due to motivational problems of the subject and was continued the next day at the point where it had been stopped).

3.5 Experimental Phases

3.5.1 Pre-Training

In order to familiarize the subjects (especially the naive ones) with the procedure, they were subjected to a pre-training phase. To make sure that all pigeons worked equally well before the onset of the discrimination training, all of them (including the experienced ones as some of them had been out of practice for a while) had to do the pre-training. The stimuli used for pre-training were irrelevant to the actual experiment. The pigeons were first trained in an autoshaping procedure, which means that a stimulus (a colored square) was presented for 10 s, followed by 5 s food access and illumination of the feeder, no matter if the pigeons had pecked at the stimulus or not. But if they pecked, presentation was immediately terminated and food was delivered. Each autoshaping session consisted of 40 trials.

When the subjects started to respond to the stimulus, autoshaping was terminated and peck-training started. There, the pigeons had to peck in response to the same stimulus 3 times within 3 seconds to receive food from the feeder. Again, each session consisted of 40 trials. The next step was a simple discrimination training between two different stimuli – the positive one was that from the prior pre-training phases (the colored square), the negative one was a new one (a differently colored square). When the pigeons had learned to discriminate these two stimuli they got further training with eight additional new stimuli (again differently colored squares), four positive and four negative ones. Thus, they had learned to discriminate between 5 positive and 5 negative stimuli in total by the end of pre-training.

3.5.2 Discrimination Training

The subjects were then assigned to the two training groups (Group No Shell and Group No Head) and were trained to discriminate between pictures containing (incomplete) snails (Class S) and pictures showing something else (Class NS). Training consisted of the presentation of 200 stimuli, 100 of Class S and 100 of Class NS. The stimuli were organized into five sets of 40 stimuli each, with one set per session being shown. Completion of all five sets (or sessions) was considered a "cycle". I created ten cycles in total, which differed from one another by the order of stimuli within each set and by the order of sets within each cycle. Training was terminated as soon as the subjects discriminated between positive and negative stimuli at a significant level in all five sessions of such a cycle (see Data Analysis). If a pigeon failed to learn the task within 100 sessions, it was discontinued.

3.5.3 Generalization Test

In a subsequent Generalization Test (Generalization Test I), I presented 80 novel non-reinforced stimuli, 40 of Class S and 40 of Class NS, to make sure that discrimination was due to mechanisms beyond rote learning on a pixel-by-pixel basis. Each test session consisted of 32 training stimuli and 8 test stimuli, and the latter were randomly interspersed into the sequence of training stimuli. The test stimuli were shown with neutral contingencies (i.e., they were shown for 10 s and afterwards disappeared no matter if the pigeon pecked or not). The training stimuli were reinforced in the same way as in training (i.e., pecks on positive stimuli were rewarded while pecks on negative stimuli resulted in a delay). Subjects which were not able to discriminate significantly between the novel instances of the training classes got additional training after Generalization Test I. Therefore, I conducted another training phase of at least 10 sessions to further increase the birds' experience with the training categories and thereby maybe enable them to eventually grasp the underlying class rule. Then they were subjected to a second run of the Generalization Test (Generalization Test II). As the test stimuli were shown with neutral contingencies in the first run the same pictures could be used again in the second run, because one-trial-learning during the first run was not possible. Only if a subject was able to pass the Generalization Test (either I or II) it was subjected to the subsequent Picture-Object Recognition Test.

3.5.4 Picture-Object Recognition Test

The Picture-Object Recognition Test was the critical test of the present experiment. It entailed three types of novel non-reinforced stimuli, with each type comprising 40 pictures. All test stimuli were derived from new pictures. Stimuli of the first type (seen part; SP) showed a snail part that had been present in the training stimuli of the respective group (and absent from the stimuli of the opposite group), namely heads for Group No Shell and shells for Group No Head. Those stimuli served mainly as a control. Namely, I wanted to make sure that the pigeons had no general problem classifying pictures that showed only isolated snail parts. Stimuli of the second type (unseen part; UP) showed the part of the snail that had not been present in the training stimuli of the respective group (but was present in the stimuli of the opposite group), that is, shells for Group No Shell and heads for Group No Head. As training instances of Class S and UP stimuli did not contain the same perceptual information but were complementary, transfer to the latter could not be based on the recognition of item-specific features, that is, idiosyncratic stimulus aspects that are used to identify particular instances but are irrelevant to categorization (Loidolt, Aust, Meran & Huber, 2003), such as, e.g., salient shapes. Furthermore, as none of the depicted parts shown in the test matched any particular snail presented during training, transfer by means of item-specific features that appeared in different body parts of any individual snail (such as, e.g., particularities of a specific snail´s skin texture) could also be ruled out as a basis of transfer. To control for transfer by means of category-specific features, that is, class-distinguishing stimulus aspects (most likely surface properties related to snail skin), I introduced a third test stimulus type (skin; SK), which showed patches of snail skin of arbitrary shape and size.

Like in the Generalization Test each test session involved 32 training stimuli with 8 interspersed test stimuli. The whole test thus consisted of 15 sessions. The test stimuli were randomly assigned to the individual sessions, with the restriction that each session included stimuli of all three types. To give a better impression of how a test session looked like, numbers of stimuli as well as sample pictures are shown for each group in Figure 5.

	Group No Head	**Group No Shell**	**Number of Stimuli per Test Session**	
			Group No Head	Group No Shell
Training Stimuli				
			32	32
Test Stimuli			8 Test Stimuli in total	
Seen part			2 - 3	2 - 3
Unseen part			2 - 3	2 - 3
Skin			2 - 3	2 - 3

Figure 5. Design of the test sessions in the Picure-Object Recognition Test, shown separately for the two groups. For Group No Head, the shells served as seen parts and the heads served as unseen parts, and vice versa for Group No Shell. Skin stimuli were the same for both groups.

3.6 Data Analysis

For statistical analysis I made use of the program Data Desk 6.0. Training performance was assessed as rho-values, a measure introduced by Herrnstein et al. (1976). It is derived from the U statistic (by using the non-parametric Mann-Whitney U Test) and gives the probability of an average positive picture being ranked above an average negative picture. When rho is 0,5, discrimination is absent; and when rho is 1,0, discrimination is perfect. With 20 positive and 20 negative stimuli, a rho of 0,676 indicates that discrimination is significant correct at the 5%-level (obtained from http://www.pigeon.psy.tufts.edu/avc/huber/Rho.htm). To reach criterion in the discrimination training, the subjects had to discriminate between positive and negative stimuli at a significant level (rho = 0,676) in all five sessions of a cycle.

All other analyses were based on mean standardized response rates that were obtained by dividing the absolute number of pecks emitted in each trial of a session (both training and test trials) by the average peck rate of that session, as measured on trials with training contingencies only. To ensure that the birds really learned the task in the training, i.e., that they grasped the underlying class rule, they had to discriminate between positive and negative pictures of the Generalization Test significantly with $\alpha = 0{,}01$ (rho = 0,651). Good baseline performance was necessary to justify any conclusions to be drawn from the results of the subsequent Picture-Object Recognition Test. Peck rates in response to positive and negative transfer stimuli of the Generalization Test and those emitted to SP, UP and SK stimuli of the Picture-Object Recognition Test were compared with each other by means of Mann-Whitney U Tests.

4 RESULTS

4.1 Pre-Training

All subjects readily learned to peck at the stimuli presented on the screen and also mastered with ease the subsequent discrimination task with ten irrelevant stimuli. Afterwards they were subjected to the training with the snail vs. non-snail stimuli.

4.2 Discrimination Training

The results of the Discrimination Training can be seen in Table 2, which shows the rho-values for each cycle and bird. The learning curves for both groups are shown in Figure 6. All birds of Group No Head acquired the discrimination between the 5th and the 8th cycle. In Group No Shell the fastest bird reached criterion in the 9th cycle. Two birds of this group (Bobbison and Verena) failed to learn the task within 100 training sessions. For those two birds training was terminated and they were excluded from further testing.

For reasons of comparison Figure 7 shows the learning curves for the pigeons of the study by Aust and Huber (2006) where they had to discriminate between pictures showing incomplete humans and pictures showing something else. The humans presented to Group No Head were devoid of heads, the humans shown to Group No Hands were devoid of hands. All birds acquired the initial discrimination between the 4th and the 9th cycle.

Table 2. Mean rho-values (averaged across the five sessions of a cycle) reached in each training cycle by the individual birds. Significant values are in italics and highlighted yellow. The birds reached criterion when discriminating at a significant level (rho ≥ 0,676) in each session of a cycle.

Cycle	**Group No Head**				**Group No Shell**			
	Daisy	**Cordula**	**Franz**	**Herbert**	**Josef**	**Klara**	**Bobbison**	**Verena**
1	0,550	0,595	0,613	0,513	0,502	0,509	0,475	0,558
2	*0,717*	0,579	*0,781*	0,602	0,627	0,630	0,519	0,564
3	*0,677*	0,427	0,674	0,626	0,502	0,646	0,593	0,560
4	*0,773*	0,518	0,483	*0,695*	0,568	0,612	0,589	0,514
5	*0,846*	*0,733*	0,658	0,631	0,561	0,493	0,536	0,572
6		*0,762*	*0,716*	*0,738*	0,648	*0,709*	0,573	0,611
7			*0,735*	*0,816*	*0,706*	*0,706*	*0,678*	0,542
8				*0,798*	*0,732*	0,586	0,582	0,659
9					*0,743*	0,587	0,646	*0,679*
10						0,633	*0,690*	0,636
11						0,625	0,652	0,645
12						0,590	*0,691*	0,647
13						*0,733*	0,494	*0,696*
14							0,572	0,667
15							0,637	0,609
16							0,526	0,603
17							0,589	0,585
18							0,672	0,638
19							0,601	*0,698*
20							0,624	0,624

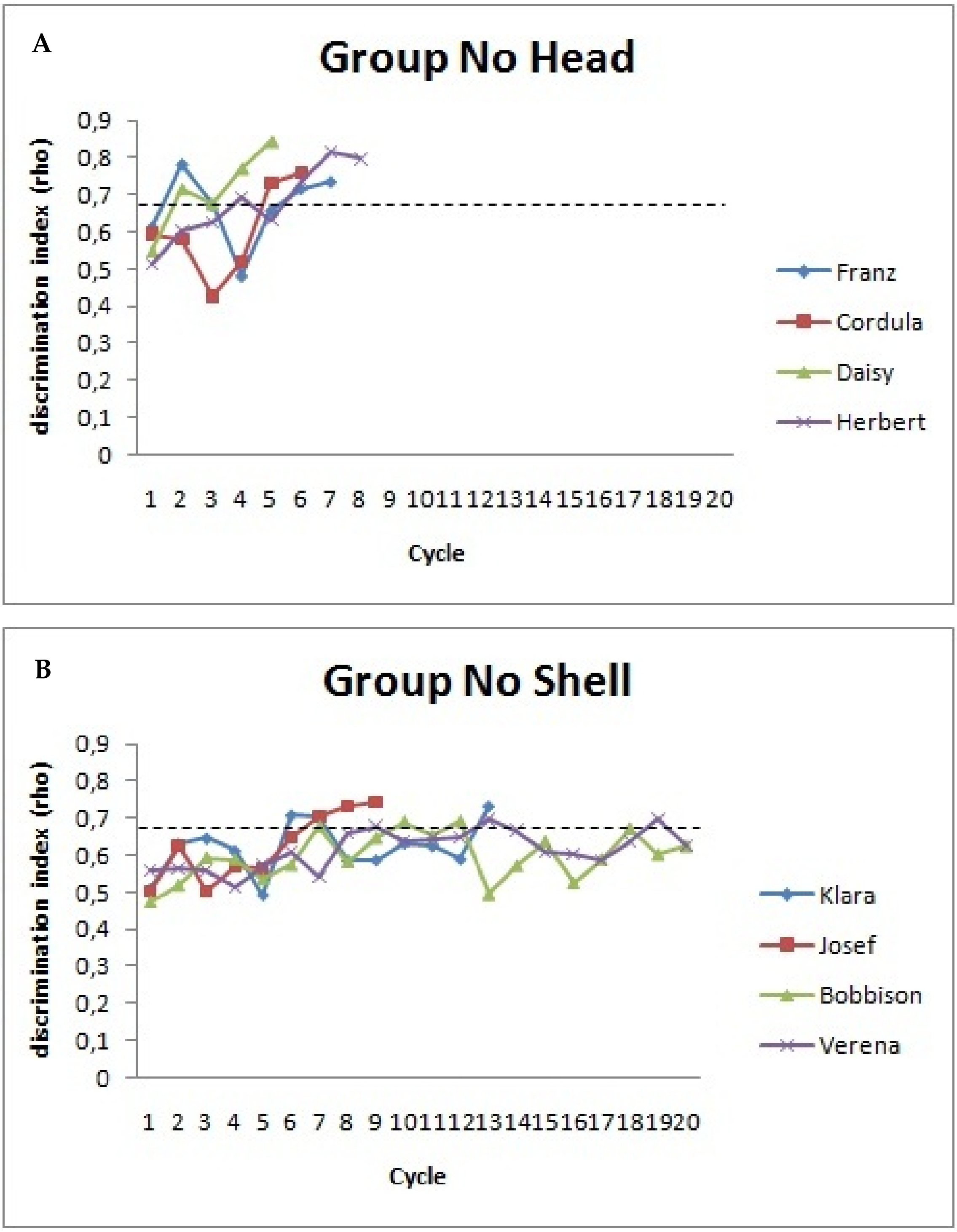

Figure 6. Acquisition performance of the individual subjects of Groups No Head (A) and No Shell (B), shown as rho-values. The dashed horizontal line indicates the limit of significance (rho = 0,676). Each cycle consisted of five sessions.

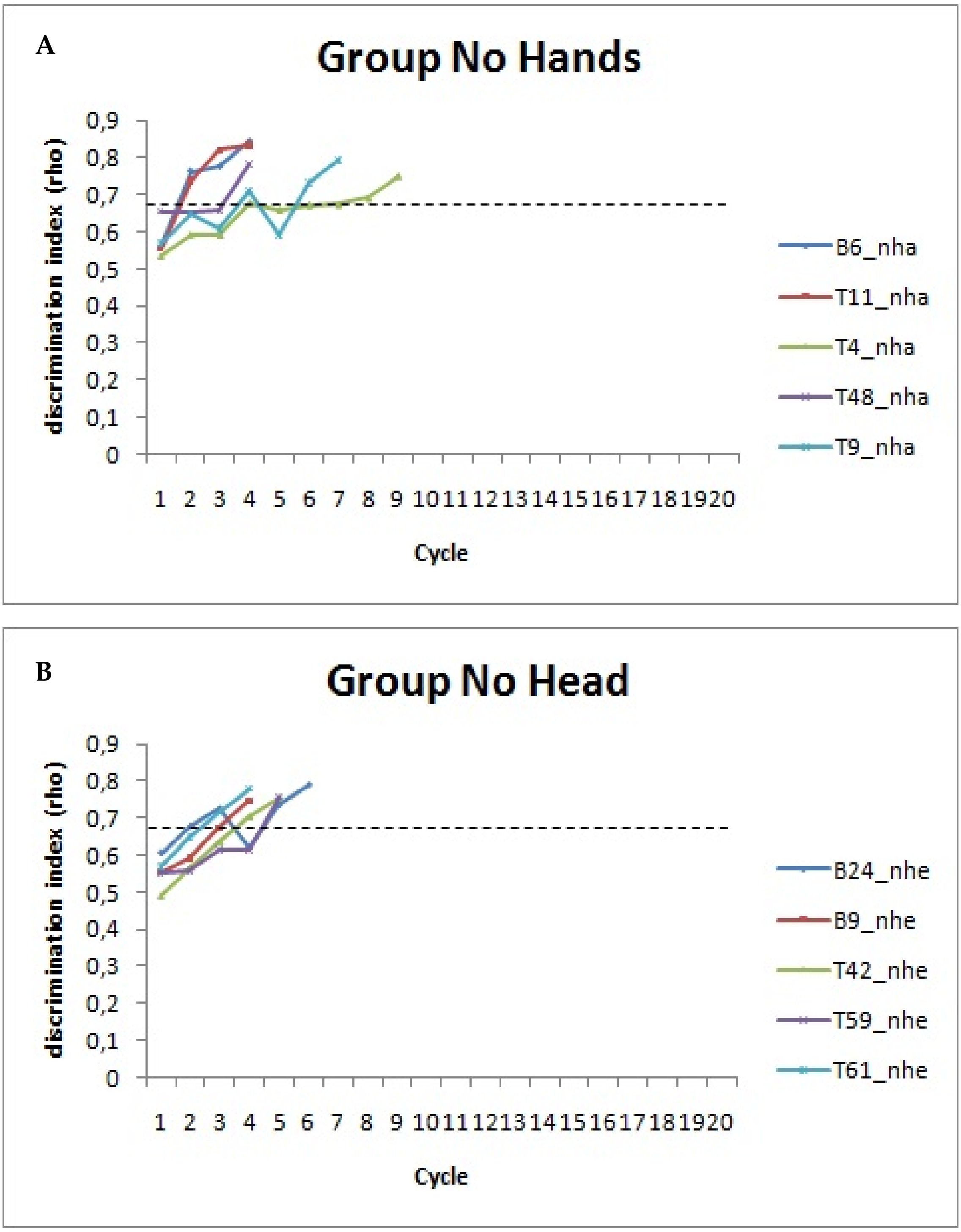

Figure 7. Acquisition performance of the individual subjects of Groups No Hands (A) and No Head (B) of Aust and Huber (2006), shown as rho-values. The dashed horizontal line indicates the limit of significance (rho = 0,676). Each cycle consisted of five sessions.

The results of the discrimination training for the two groups of the present study are summarized in Figure 8, which shows the number (±SD) of sessions needed to reach criterion, averaged across subjects. Interestingly, learning speed differed significantly between the two groups (Mann-Whitney-U Test; *p* = 0,0202). Group No Head required 32 (±6) sessions (range 25-40) to reach criterion, whereas Group No Shell needed more than twice as many sessions, namely 77 (±27), but with large variations among subjects (range 45-100). (And note that two birds of this group did not reach criterion within 100 sessions at all). The comparison between Group No Head and just the two successful birds of Group No Shell (striped bar) still indicates a tendency for the birds of Group No Shell to have been the faster ones (although the small n of 2 did not allow for a statistical test to confirm this).

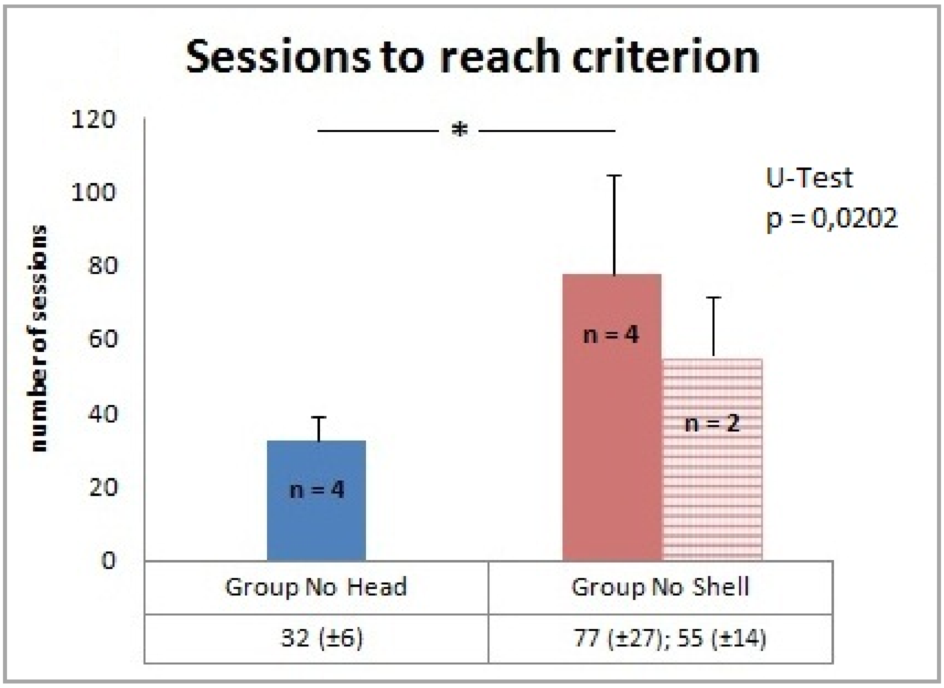

Figure 8. Mean number (±SD) of sessions needed to reach criterion (or until training was aborted), shown separately for Groups No Head (blue bar; n = 4) and No Shell (red bar; n = 4). Performance of the two successful birds of Group No Shell (i.e., excluding the data of the two subjects that were discontinued after 100 sessions without learning) is illustrated by an additional (striped) bar. Means were taken across the subjects of each group.

4.3 Generalization Test

Six subjects out of eight learned the discrimination task and were then tested with 80 novel non-reinforced stimuli, 40 of Class S and 40 of Class NS (Generalization Test I). The results are summarized in Figure 9 which shows separately for each group performance of all subjects as mean standardized response rates. Peck rates beyond average (> 1) indicate that the pictures were treated as positives rather than as negatives; peck rates below average (< 1) indicate that the pictures were treated as negatives rather than as positives.

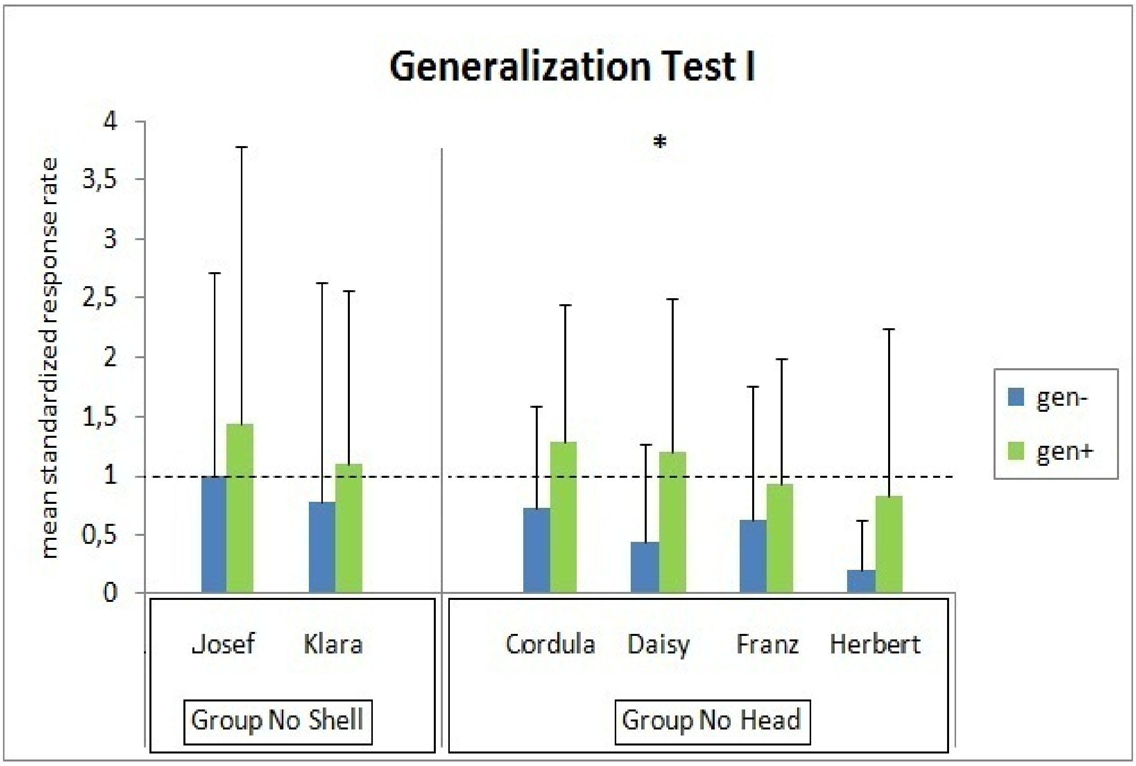

Figure 9. Results of Generalization Test I. Performance is shown separately for the birds of the two groups as mean standardized response rates (±SD). gen- = novel negative stimuli (Class No Snail; NS), gen+ = novel positive stimuli (Class Snail; S). The dashed horizontal line indicates the average response level.

All birds showed a tendency to peck more at novel positives than at novel negatives in the Generalization Test, but with standard deviations being very high, i.e., with a large variability of pecking responses between the stimuli of each class. Actually, only Daisy managed to discriminate the test stimuli at a significant level (*p* = 0,0001). Due to my failure (the test cycle of Herbert only contained five sessions instead of ten), statistical analysis concerning Herbert was only done for five sessions, but within these, he, as well, failed to discriminate significantly. I repeated the Generalization Test (Generalization Test II) for all subjects except Daisy after some additional training (see Methods). The results of this test are illustrated in Figure 10.

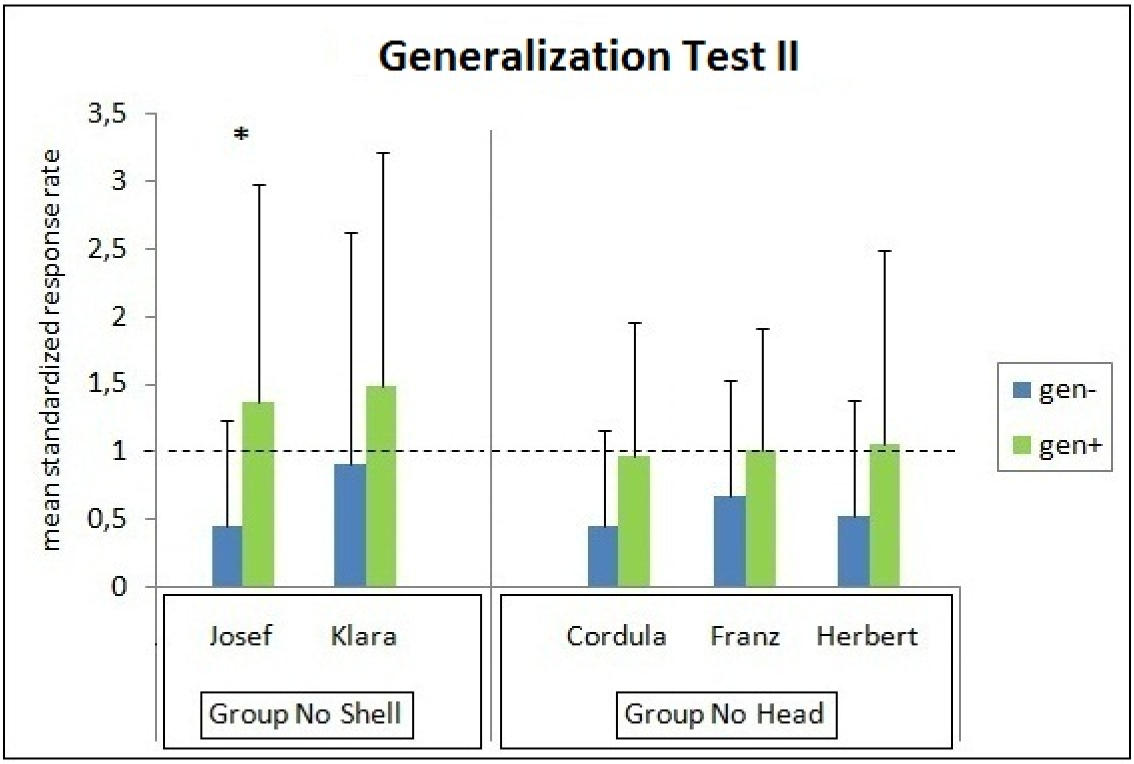

Figure 10. Results of Generalization Test II. Performance is shown separately for the birds of the two groups as mean standardized response rates (±SD). gen- = novel negative stimuli (Class No Snail; NS), gen+ = novel positive stimuli (Class Snail; S). The dashed horizontal line indicates the average response level.

As revealed by Mann-Whitney U Tests, there was one more bird, Josef, who now managed to generalize significantly to novel instances of the training classes (*p* = 0,0092). Similar as in Generalization Test I, a (non-significant) tendency to peck more on positive than on negative stimuli could be observed in all other birds. Table 3 summarizes the results of the first and the second Generalization Test as mean standardized response rates, as well as the results of the Mann-Whitney U Tests comparing performance between the positive and negative transfer stimuli (for the corresponding results obtained by Aust and Huber in 2006 see Appendix, Table 6).

Table 3. Results of the two Generalization Tests shown as mean standardized response rates separately for each subject (columns gen- and gen+), as well as the results of the Mann-Whitney U Tests (columns gen-/gen+; *p*-values, $\alpha = 0{,}01$) comparing performance between the positive and the negative test stimuli (significant differences are in italics and highlighted yellow).

Group	Subject	Generalization Test I			Generalization Test II		
		gen-	gen+	gen-/gen+	gen-	gen+	gen-/gen+
No Head	**Cordula**	0,733	1,283	0,0214	0,448	0,972	0,0184
	Daisy	0,438	1,191	*0,0001*			
	Franz	0,629	0,925	0,0333	0,670	1,008	0,0626
	Herbert	0,196	0,835	0,4165	0,532	1,063	0,1504
No Shell	**Klara**	0,769	1,099	0,2263	0,444	1,369	0,0999
	Josef	0,996	1,442	0,2294	0,904	1,489	*0,0092*

Note: gen- = negative transfer stimuli; gen+ = positive transfer stimuli.

Eventually, one subject of each group, Daisy and Josef, had solved the task and were subsequently subjected to the Picture-Object Recognition Test.

4.4 Picture-Object Recognition Test

Presentation of my results as the arithmetic mean of the standardized response rates - as was done in Aust and Huber (2006) – was found to convey a somewhat misleading picture. Namely, some of the depicted values appeared to be in disagreement with the results of the corresponding Mann-Whitney U Tests. This was due to wide variations in peck rates within the individual stimulus types leading to extreme outliers and large standard deviations. Therefore, I decided to illustrate my results not only by means of the arithmetic mean (Figure 12; to make them comparable with the data of Aust and Huber), but also as box plots, which are based on medians (Figure 11).

The results of the present study are summarized as mean standardized response rates in Table 4. Peck rates on the three test stimulus types were compared with each other and with performance on the positive and the negative generalization test stimuli (Mann-Whitney U Tests; see Table 5). The primary focus was thereby with the differences between peck rates in reaction to unseen parts versus skin stimuli. (All other comparisons provided supplementary information but were nevertheless valuable.) Therefore, analysis consisted *a priori* of eight separate questions. Thus, I did not make any Bonferroni corrections, as would have been necessary with tests for the existence of any effect of stimulus type at all (Perneger, 1998). To provide a direct comparison of my results with the study by Aust and Huber (2006), Table 6 shows the results of the Picture-Object Recognition Test obtained in their study as mean standardized response rates and Table 7 shows the results of the Mann-Whitney U Tests comparing performance on the three test stimulus types (p-values; $\alpha = 0{,}05$) revealed from their analysis (please see Appendix, Supporting Information).

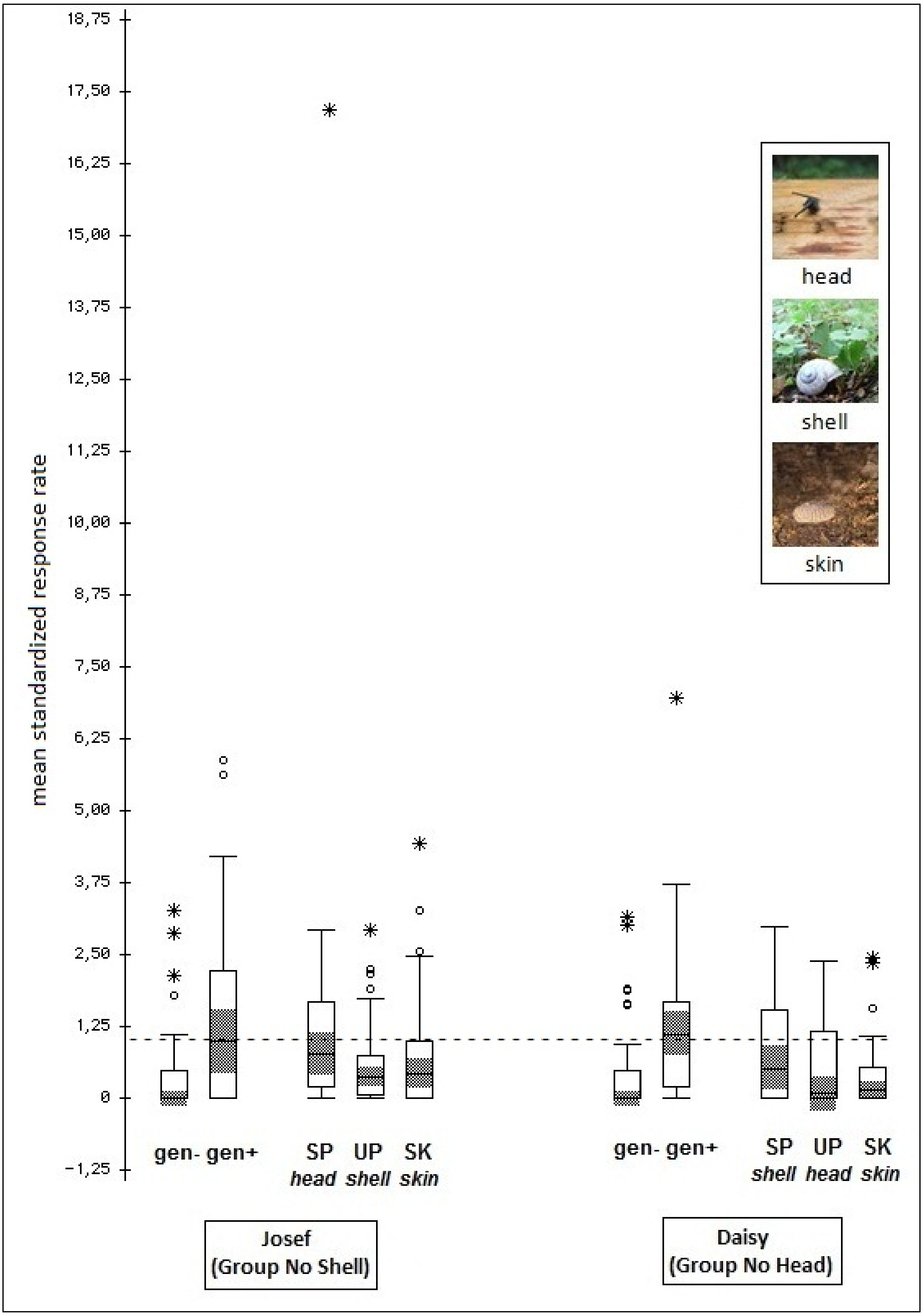

Figure 11. Results of the Picture-Object Recognition Test with peck rates on seen parts, unseen parts and skin stimuli, shown as box plots. For comparison reasons the results of the Generalization Test are shown as well. The dashed horizontal line indicates the average level of performance. Each box plot has the following components. The central

box depicts the middle half of the data between the 25th and the 75th percentile. The horizontal line across the box marks the median, and the shaded area placed symmetrically around the median marks the confidence interval. The whiskers extending from the top and bottom of the box depict the extent of the main body of the data (≤ 1.5 x box length). Extreme data values (≤ 3.0 x box length) are plotted with a circle, and very extreme values (i.e., data beyond this limit) are plotted with a starbust. Note the extreme outliers that were responsible for the large standard deviations and some (apparent) inconsistencies between the columns of Figure 12 (top panel) and the corresponding Mann Whitney U Tests. gen- = novel negative stimuli shown in the Generalization Test; gen+ = novel positive stimuli shown in the Generalization Test. SP = seen part stimuli shown in the Picture-Object Recognition Test; UP = unseen part stimuli; SK = skin stimuli.

The main results of the current study can be summarized as follows. Most importantly, peck rates to UP and SK stimuli did not significantly differ in either bird.

Josef (Group No Shell) responded more to SP stimuli than to UP and SK stimuli and the difference between SP and UP stimuli was even significant (p = 0,041). This indicates at least some tendency to treat SP stimuli more like positives than UP stimuli. Compared to the Generalization Test, there were significant differences between the negative test stimuli of the Generalization Test and all three test stimulus types of the Picture-Object Recognition Test, and this difference was most pronounced for the SP stimuli (see Table 5). No significant differences were found between the positive generalization stimuli and any of the three test stimulus types of the Picture-Object Recognition Test. Nevertheless, it must be kept in mind that variations within all the stimulus types were high, that peck rates to both UP and SK stimuli were below average (< 1) and that the relatively high peck rate to SP stimuli (1,345) was due to just one single — extreme — outlier (see Figure 11). Hence, it cannot be concluded that Josef treated any type of test stimuli rather as positive than as negative.

Daisy (Group No Head) showed no significant differences between any stimulus types (Table 5). Nevertheless there was at least a weak tendency to respond more to SP than to UP and SK stimuli. Furthermore, there was a significant difference in responding to the positive test stimuli of the Generalization Test and to the UP as well as the SK stimuli, but no significant difference to the SP stimuli. In turn, there was a significant difference in responding to the negative stimuli of the Generalization Test and the SP stimuli, but no such difference was found in the case of UP and SK stimuli. But again, the high variations within all stimulus types and the fact that peck rates of all three test types were below average (< 1) warrant caution and do not allow for any strong conclusions in terms of differential responding to different types of test stimuli.

Table 4. Results of the Picture-Object Recognition Test shown as mean standardized response rates (±SD) separately for the two subjects.

Stimuli	Josef (Group No Shell)	Daisy (Group No Head)
SP	1,345 (2,711)	0,798 (0,905)
UP	0,597 (0,716)	0,626 (0,834)
SK	0,755 (0,983)	0,424 (0,605)

Note: SP = seen part stimuli of the Picture-Object Recognition Test; UP = unseen part stimuli; SK = skin patches.

Table 5. Results of the Mann-Whitney U Tests (p-values; α = 0,05) comparing performance on the three test stimulus types of the Picture-Object Recognition Test (SP, UP and SK) with each other and with the performance on the transfer stimuli of the Generalization Test.

Subject	gen-/gen+	gen-/SP	gen-/UP	gen-/SK	gen+/SP	gen+/UP	gen+/SK	SP/UP	SP/SK	UP/SK
Josef	*0,0092*	*0,0003*	*0,0256*	*0,0289*	0,9961	0,2492	0,2312	*0,041*	0,1218	0,7639
Daisy	*0,0001*	0,0145	*0,1317*	0,1689	*0,1197*	0,0152	*0,0007*	0,3372	0,7677	0,1137

Note: gen- = negative transfer stimuli of the Generalization Test; gen+ = positive transfer stimuli of the Generalization Test; SP = seen part stimuli of the Picture-Object Recognition Test; UP = unseen part stimuli; SK = skin patches. Significant differences are in italics. The (most important) comparison between unseen part stimuli and skin stimuli are highlighted in pink.

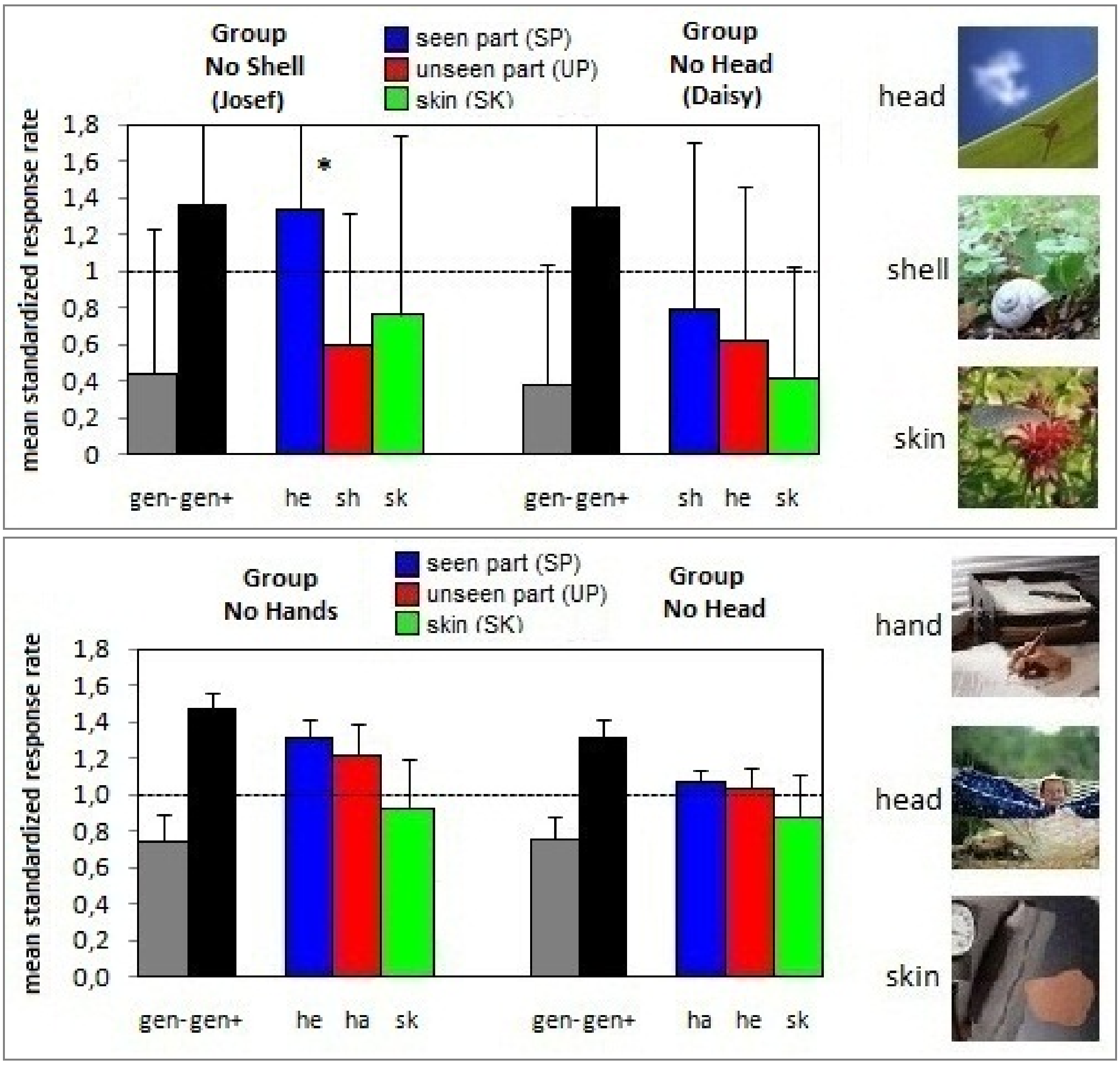

Figure 12. Results of the Picture-Object Recognition Test with seen parts, unseen parts and skin stimuli. Performance is shown as the arithmetic mean of the mean standardized response rates (±SD) obtained in the present experiment (top panel) and by Aust and Huber (2006; bottom panel), as well as examples of the individual types of test stimuli (right). For comparison reasons the results of the Generalization Test are shown as well. For the present study standard deviations among the stimuli of each type are shown, in the case of the Aust and Huber study (2006) standard deviations among the subjects of each group are shown. The dashed horizontal line indicates the average level of performance. gen- = novel negative stimuli shown in the Generalization Test; gen+ = novel positive stimuli shown in the Generalization Test. SP = seen part stimuli shown in the Picture-Object Recognition Test; UP = unseen part stimuli; SK = skin stimuli.

Comparing the two studies, the most obvious — and important — difference is that the subjects in Aust and Huber (2006) showed significantly higher peck rates to UP than to SK stimuli whereas the subjects in my study did not show any such difference, with Josef even showing a slightly reverse tendency. Furthermore, Daisy responded below average to all three test stimulus types, Josef responded above average only to SP stimuli (and, as outlined above, this was due to just one extreme data value). This is in contrast to the performance of the birds in Aust and Huber (2006). Although the peck rates to SP and UP stimuli lay just slightly above average in the case of Group No Head, all birds treated the SP and the UP stimuli as positives rather than as negatives, and only peck rates to SK stimuli were significantly lower (i.e., below average).

5 DISCUSSION

The experiments by Aust and Huber (2006, 2010) provided evidence of pigeons' ability to recognize the correspondence between pictures and objects at a level beyond mere feature discrimination. Namely, they provided evidence of representational insight — at least in the sense of transfer of learned feature associations from real objects to pictures. It is evident that display of such an ability can only be expected if a subject has experience with live representatives of the category in question, and, indeed, the results of a number of studies have confirmed the crucial role of category familiarity for picture-object recognition (e.g., Aust & Huber, 2010; Truppa, 2008; Watanabe, 1997b).

In the present study, the experiment by Aust and Huber (2006) was replicated, but with pigeons being trained on a category they had no prior real-life experience with, namely "snails". The rationale of the experiment was the following. If differential responding to UP (unseen part) and SK (skin) stimuli in Aust and Huber was indeed due to representational insight (and thus mediated by experience with live humans), the pigeons in the present study should display no such difference due to their lack of experience with real snails. Such a result would be further — indirect — evidence that pigeons are capable of representational insight as long as they are tested with a category which they have already gained experience with in real life. At the same time it would confirm that the Complementary Information Procedure is an appropriate method for investigating picture-object recognition. Indeed, the results of the present study differed from the ones obtained by Aust and Huber (2006) in several respects. In the following, performance in the three phases of the two studies will be compared separately.

(1) Discrimination training. Learning speed, i.e., the number of training cycles required to reach criterion, was different in the two studies. On average, pigeons were faster in learning the discrimination between humans and non-humans than between snails and non-snails, and two birds failed to learn the latter discrimination at all. There are at least two obvious explanations that may account for this difference. On the one hand, it is possible that humans and their parts are perceptually more salient to pigeons than snails, which could have facilitated the extraction of the category-defining features (or memorization of individual pictures). On the other hand, faster learning of the "human" than of the "snail" category could indeed have been due to a "familiarity effect" (see Wilkinson, Specht & Huber, 2010; Specht H.L., 2009: Masterthesis, Vienna 2009). This means that real-life experience could have facilitated learning of the "human" task as opposed to the "snail" task. In any case, the strategy by which the pigeons in the present experiment acquired the discrimination is not obvious from training performance. Delayed learning as compared to Aust and Huber is compatible with either the need to memorize every instance and its contingency individually (rote learning) or difficulties the pigeons encountered in abstracting the category-defining features (learning of a perceptual class.)

Furthermore, there was a difference in learning speed between Group No Shell and Group No Head in the present study. Namely, the subjects of Group No Head needed significantly fewer cycles to reach criterion (and two birds of Group No Shell even failed to learn the task). One possible explanation for this difference may be that the shells present in the training pictures of Group No Head were more conspicuous for the pigeons and therefore easier to recognize than the heads present in the training pictures of Group No Shell. In particular, the distinct helix structure of snail shells might have facilitated the distinction between Class S and Class NS. In addition, stimuli containing shells could have been better discriminable from the background because of their distinct colors, which contrasted with the background much more than that of snail bodies (and heads), particularly when the latter were presented on soil or on wood. Furthermore the snail figures in the training stimuli of Group No Head were, for the most part, bigger than those presented to Group No Shell (due to the fact that shells were, on average, larger than heads), which might also have differentially affected target detectability in the two groups.

Overall, we may assume that snail shells made a potentially better category-defining feature than the snail-bodies or heads. This finding has a parallel in the studies by Aust and Huber (2006; 2010), who found that human heads were more important for the formation of an appropriate and comprehensive representation of "humans" than were hands. Correspondingly, the pigeons of Group No Hands learned the discrimination between humans and non-humans faster than Group No Head.

(2) Generalization Test. Only two birds of the present study (one of each group) pecked significantly more on novel snail than on novel non-snail stimuli in the Generalization Test, and one of them did so only after additional training. All other birds showed just a non-significant tendency to classify the novel stimuli correctly. The most parsimonious explanation to account for the significant transfer displayed by the two successful birds would be in terms of a generalization mechanism based on perceptual similarity of test stimuli with individually memorized training pictures (i.e., exemplar learning). Alternatively, they may have abstracted from the training stimuli one or more category-specific features and recognized them also in the novel pictures. But overall, the pigeons' ability to transfer their knowledge from training stimuli to novel instances was strongly limited in the present study, which indicates substantial deficits in the birds' ability to form an appropriate and comprehensive target representation. Rather, it suggests that classification was bound to a considerable extent (although not fully) to the appearance of individually learned category instances. In the study by Aust and Huber (2006),

by contrast, all pigeons showed good transfer to new people-present and people-absent pictures, which indicates that they had formed a representation of (incomplete) humans. Presumably, they did not learn the stimuli by rote (at least not on a pixel-by-pixel basis), but abstracted the category-relevant features. The same reasons that may have accounted for the differences in learning speed between the two studies could have been responsible for different performance in the Generalization Test, namely, differences in either perceptual conspicuousness (or distinctiveness) between humans and snails, or in the birds' real-life experience with the trained categories.

(3) Picture-Object Recognition Test. The crucial test in order to examine representational insight was the Picture-Object Recognition Test. The results revealed that both birds classified the unseen parts (UP) of a snail as negative stimuli, and no difference in responding was found between true (previously unseen) snail parts (UP) and arbitrary (non-representative) patches of snail skin (SK).

This suggests that the pigeons' lack of experience with live representatives of the category "snail" may have caused them to treat the previously unseen parts of the snail, namely the head or the shell, respectively, like negative stimuli. This finding is in sharp contrast to the results of Aust and Huber (2006), who found that pigeons treated pictures of unseen parts of humans as positives and pecked at them significantly more than to non-representative skin patches. It was concluded that the pigeons had based their responding on representational insight, and the different outcome of the Picture-Object Recognition Test of the present study lends further credit to this assumption.

Interestingly, only the No Shell pigeon (Josef) showed a significant tendency to peck more at SP than at UP stimuli. The No Head pigeon (Daisy) did not respond significantly more to shells (i.e., the seen parts) than to heads (i.e., the unseen parts). One possible explanation for the different performance of the two pigeons on their SP stimuli could be that variability in the appearance of snail heads may have been lower than variability in the appearance of snail shells. On closer inspection, the heads shown in the Picture-Object Recognition Test looked very similar to the ones presented in training regarding their color and their shape, whereas the shells varied strongly in shape and/or color. The different response rates emitted to seen parts by the No Shell and the No Head pigeon could thus have been due to differences in the perceptual similarity between the two groups' positive training stimuli and the corresponding seen parts stimuli.

Thereby, the No Shell pigeon (Josef) may have used a combination of both the surface properties of skin (i.e., texture and color cues) and the characteristic shape of the head. Regarding Daisy, the No Head pigeon, the possibility may be considered that she used some kind of a "compound" feature to classify the training pictures, that is, the shell in combination with the headless body. This means that during training she might have learnt that only figures consisting of both a trunk and a shell are rewarded. Thus, shells alone (SP stimuli) may not have been classified significantly more as positives than the UP stimuli because – for the pigeon – they lacked crucial information, namely, the trunk. An alternative explanation for Daisy's results may be that she learned the training task by exclusively attending to the shells and that these were, by accident, more similar to the shells shown in the Generalization Test than to the ones of the SP pictures in the Picture-Object Recognition Test. If so, she could have passed the Generalization Test, but would have failed on the SP stimuli (and of course, also on the UP and the SK stimuli, which contained no shells at all). Although I was very careful in choosing the pictures of the different tests and stimulus types, this possibility cannot be entirely excluded.

Comparing the three test stimulus types of the Picture-Object Recognition Test with the test stimuli of the Generalization Test reveals the following. In the case of the No Shell pigeon (Josef) there were significant differences between the negative pictures of the Generalization test and all three test stimulus types of the Picture-Object Recognition Test but no significant differences between the positive pictures of the Generalization Test and either of the three stimulus types. Hence, one may be tempted to assume that Josef treated all test stimulus types (SP, UP and SK) rather like positive than like negative training stimuli. However, it must not be forgotten that, in absolute terms, response rates were low (< 1) and/or contaminated by high standard deviations, which demands extreme caution. Similarly, the significant difference between seen parts and unseen parts seems to indicate that the pigeon did make a difference between "familiar" and "unfamiliar" parts of a snail, but again, one should be careful not to over-interpret these results for the outlined reasons.

Regarding the No Head pigeon (Daisy) there was a significant difference between the negative pictures of the Generalization Test and the SP stimuli of the Picture-Object Recognition Test, but not between the positive pictures of the Generalization Test and the SP stimuli which suggests that she, as well, may have recognized something "familiar" in the SP pictures (although there was no significant difference to the UP stimuli). There were also significant differences between the positive pictures of the Generalization Test and the UP and SK stimuli which indicates that the latter were treated more like negatives than the SP stimuli. But as with Josef, the large differences in response rates within the individual stimulus types demand caution in interpreting also Daisy's performance.

In summary, the results of the current thesis showed that the Complementary Information Procedure (Aust & Huber, 2006) yielded different results when used with an unfamiliar object class than with a class that pigeons have real-life experience with. The most important finding of my study was that, in contrast to the pigeons in Aust and Huber, the two birds that accomplished the Picture-Object Recognition Test of the present experiment did not respond differently to UP and SK stimuli. Therefore, my findings indirectly confirm the assumption that information about real objects can be transferred to pictures of objects of the same category (Aust & Huber, 2006; 2010). That is, pigeons are able to recognize the correspondence between parts of a real object and the equivalent parts in pictures at a level beyond mere feature discrimination.

But although the present work seems to justify the assumptions made by Aust and Huber, one has to keep in mind that only two subjects were tested in the (most important) Picture-Object Recognition Test, and, moreover, these two showed slightly different behaviour. Furthermore, the large variations in peck rates within the individual stimulus types (SP, UP and SK) entail that these results may, at best, reflect some tendencies. Finally, it must be kept in mind that generalization to novel category instances was strongly limited in all birds and that response rates of Daisy and Josef to *all* test stimulus types in the Picture-Object Recognition Test — including SP — were quite low. This seems to point to a general problem of the pigeons to properly learn and transfer the discrimination between snail and non-snail pictures (i.e., to form an appropriate and comprehensive target representation). Whether these difficulties were entirely due to familiarity effects (and thus indirect support of the notion of representational insight) seems doubtful, at least. Rather, the pigeons’ problems with the “snail” category may have had a perceptual basis, and this could easily have interfered with the effects of (lacking) picture-object recognition. For all these reasons, one has to be very cautious not to over interpret the present results.

It is beyond dispute that further studies are needed to clarify at which cognitive level pigeons are able to relate pictures to the real world. To this end, investigations with more subjects would be of interest for future research. Furthermore, it would be of importance to investigate which parts of a snail are actually crucial for categorization. To examine this, pigeons could be trained to discriminate snail versus non-snail pictures, whereby the snails are left intact, i.e., without modifying or removing parts of them. Afterwards they could be tested for transfer to pictures of isolated snail parts. Another possibility to further test the conclusions drawn from the results of the present study would be to repeat this experiment with another category the pigeons are not familiar with, like, for example, fish or horses. Finally, it would be interesting to apply the Complementary Information Procedure to various other nonhuman species and investigate how they will manage to solve Picture-Object Recognition Tasks. All these lines of research may eventually contribute to a better understanding of how pigeons and other nonhuman species process pictures and may thus be relevant to a wide range of studies on animals' visual cognition.

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APPENDIX

Supporting Information

Table 6. Mean standardized response rates obtained in the Generalization Test (columns gte- and gte+) and in the Picture-Object Recognition Test (columns sp, up and sk) by Aust and Huber (2006).

Subject	gte-	SD	gte+	SD	sp	SD	up	SD	sk	SD
B6_nha	0,559	0,706	1,585	0,772	1,175	0,821	0,963	0,796	0,512	0,612
T4_nha	0,750	0,539	1,500	0,592	1,315	0,929	1,184	0,587	1,112	0,867
T9_nha	0,883	0,749	1,445	0,691	1,296	0,607	1,395	0,557	1,181	0,549
T11_nha	0,690	0,615	1,490	0,535	1,466	0,833	1,240	0,688	0,966	0,790
T48_nha	0,877	0,581	1,369	0,514	1,299	0,777	1,333	0,791	0,882	0,789
B24_nhe	0,626	0,639	1,274	0,516	1,082	0,781	1,174	0,633	0,957	0,868
B9_nhe	0,652	0,615	1,374	0,834	0,999	0,922	1,045	0,776	0,613	0,728
T42_nhe	0,858	0,556	1,400	0,519	1,077	0,519	1,107	0,450	1,071	0,728
T59_nhe	0,878	0,674	1,368	0,550	1,057	0,848	0,953	0,675	0,664	0,736
T61_nhe	0,784	0,707	1,177	0,623	1,171	1,045	0,883	0,644	1,114	0,763
mean_nha	0,752	0,136	1,478	0,079	1,310	0,103	1,223	0,167	0,931	0,262
mean_nhe	0,759	0,116	1,318	0,093	1,077	0,062	1,033	0,117	0,884	0,232
mean_all	0,756	0,119	1,398	0,117	1,194	0,147	1,128	0,169	0,907	0,235

Note: _nha = subject(s) of Group Nohands; _nhe = subject(s) of Group Nohead; _all = subjects of both groups; gte+ = positive transfer stimuli in the generalization test; gte- = negative transfer stimuli in the generalization test; sp = seen part in the picture-object recognition test; up = unseen part in the picture-object recognition test; sk = skin in the picture-object recognition test; SD = standard deviations of the values from the preceding column.

Table 7. Results of the Mann-Whitney U Tests (p-values; α = 0,05) obtained by Aust and Huber (2006) comparing performance on the three test stimulus types of the Picture-Object Recognition Test (sp, up and sk) with each other and with the performance on the transfer stimuli of the Generalization Test.

Subject	**gen-/gen+**	**gen-/up**	**gen-/sp**	**gen-/sk**	**gen+/up**	**gen+/sp**	**gen+/sk**	**sp/up**	**sp/sk**	**up/sk**
B6_nha	*≤ 0,0001*	*0,0026*	*≤ 0,0001*	0,7622	*≤ 0,0001*	*0,0066*	*≤ 0,0001*	0,0821	*≤ 0,0001*	*≤ 0,0001*
T4_nha	*≤ 0,0001*	*≤ 0,0001*	*0,0003*	*0,0277*	*0,0033*	*0,0287*	*0,0004*	0,8431	0,1185	0,0927
T9_nha	*0,0014*	*0,0002*	*0,0019*	*0,0155*	0,5739	0,1372	*0,0188*	0,2487	0,1994	*0,0182*
T11_nha	*≤ 0,0001*	*≤ 0,0001*	*≤ 0,0001*	0,1076	*0,0400*	0,4195	*≤ 0,0001*	0,0839	*≤ 0,0001*	*0,0077*
T48_nha	*0,0002*	*0,0040*	0,0065	0,6279	0,5041	0,4390	*≤ 0,0001*	0,7914	*0,0005*	*0,0002*
B24_nhe	*≤ 0,0001*	*≤ 0,0001*	*0,0027*	*0,0479*	0,2335	0,1815	*0,0028*	0,4715	0,2139	*0,0122*
B9_nhe	*≤ 0,0001*	*≤ 0,0001*	*0,0047*	0,0837	0,2207	0,0993	*0,0052*	0,4715	0,2139	*0,0122*
T42_nhe	*0,0001*	0,1260	*0,0481*	0,1726	*0,0043*	*0,0039*	*0,0027*	0,7105	0,4345	0,2018
T59_nhe	*0,0008*	0,6046	0,3984	*0,0437*	*0,0009*	*0,0086*	*≤ 0,0001*	0,6400	*0,0012*	*0,0011*
T61_nhe	*0,0052*	0,3879	0,0936	*0,0177*	*0,0202*	0,3759	0,5005	0,2568	0,7047	0,0648

Note: _nha = subject(s) of Group Nohands; _nhe = subject(s) of Group Nohead; gen- = negative transfer stimuli of the Generalization Test; gen+ = positive stimuli of the Generalization Test; sp = seen part of the Picture-Object Recognition Test; up = unseen part; sk = skin patches. Significant differences are in italics. The (most important) comparison between unseen part stimuli and skin stimuli are highlighted in pink.

Figure A1. Examples of positive training stimuli (S+) that were shown to Group No Head.

Figure A2. Examples of positive training stimuli (S+) that were shown to Group No Shell.

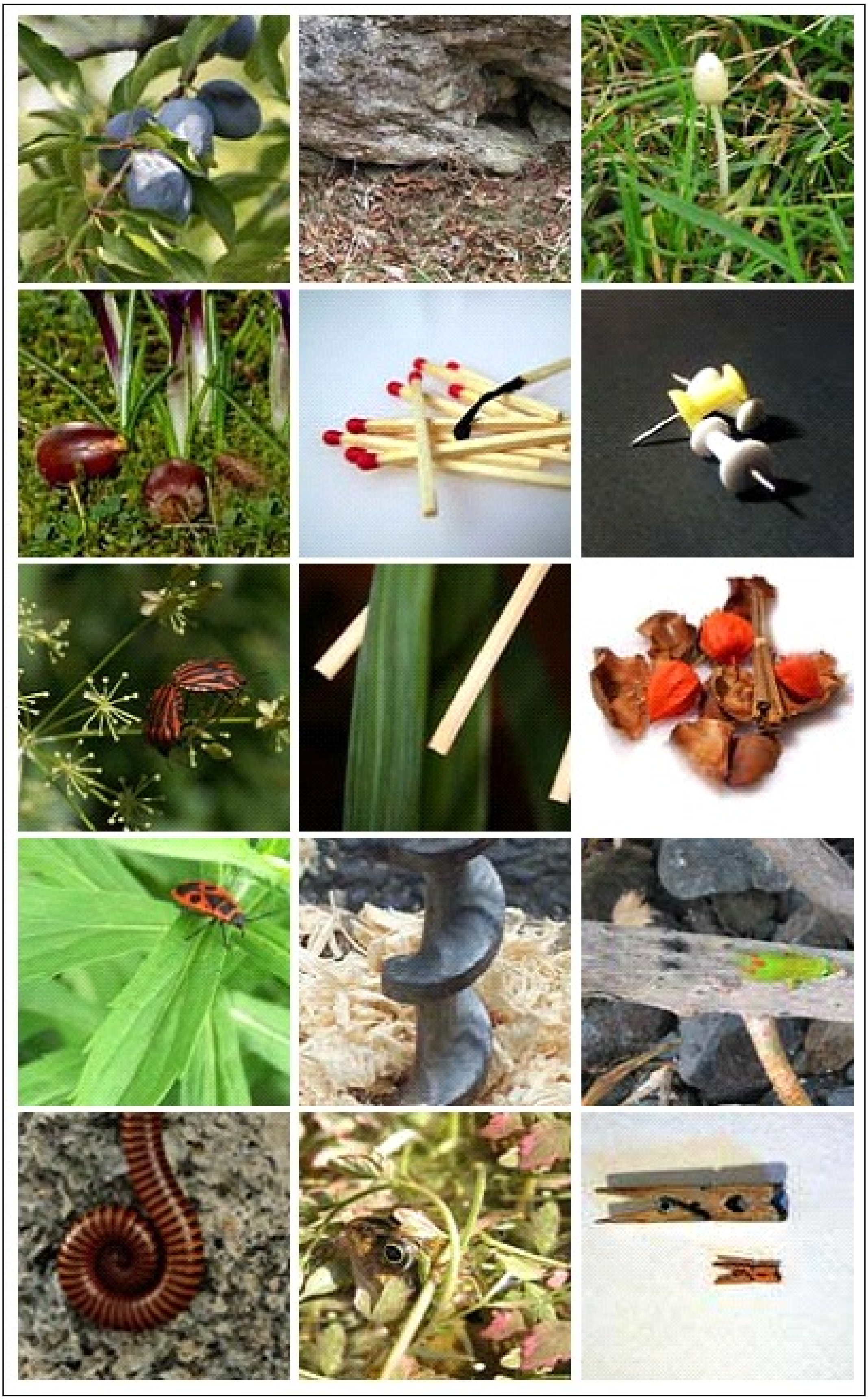

Figure A3. Examples of negative training stimuli (S-) that were shown to both subject groups.

Figure A4. Examples of positive test stimuli (S+) that were shown to Group No Head in the Generalization Test.

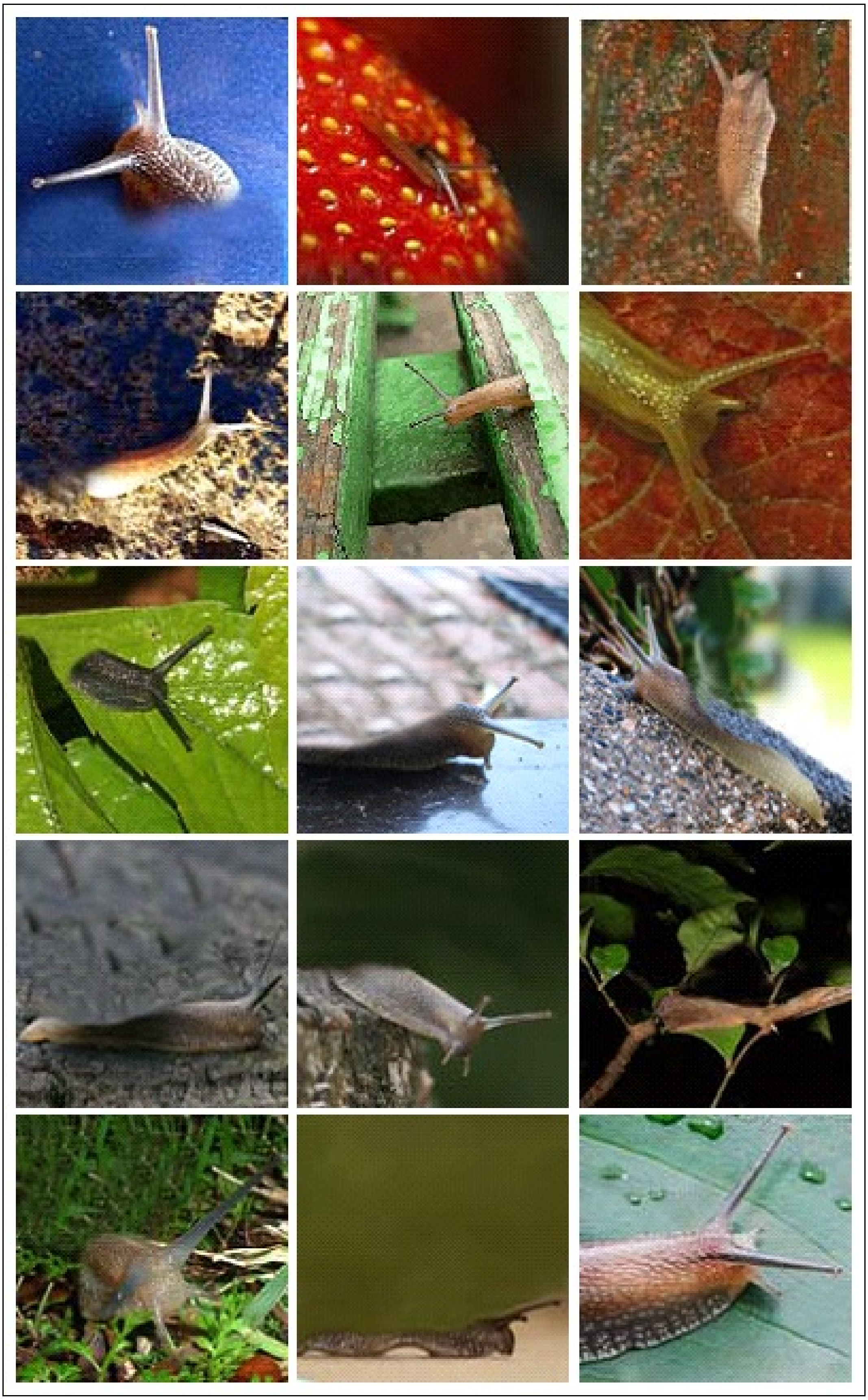

Figure A5. Examples of positive test stimuli (S+) that were shown to Group No Shell in the Generalization Test.

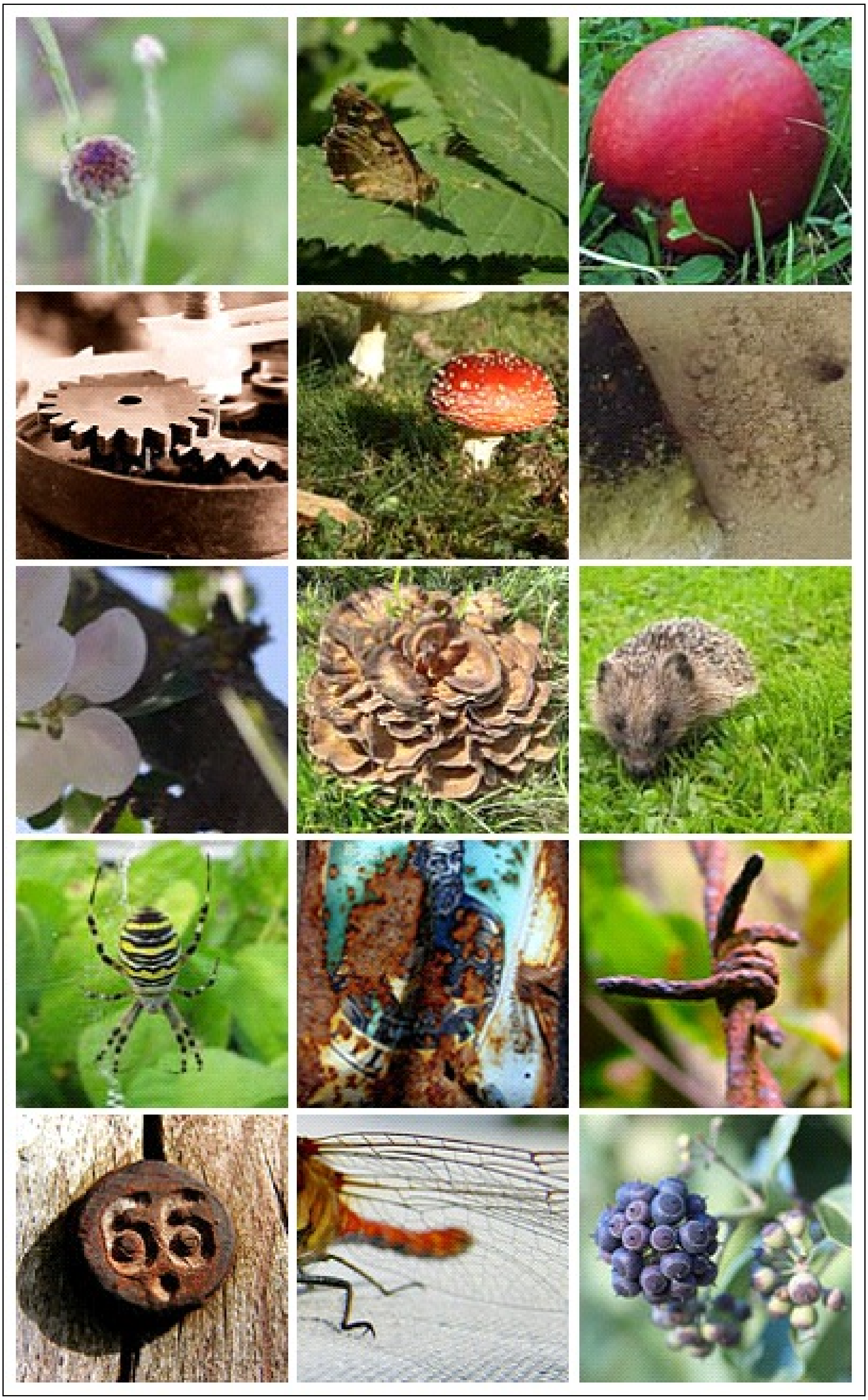

Figure A6. Examples of negative test stimuli (S-) that were shown to both subject groups in the Generalization Test.

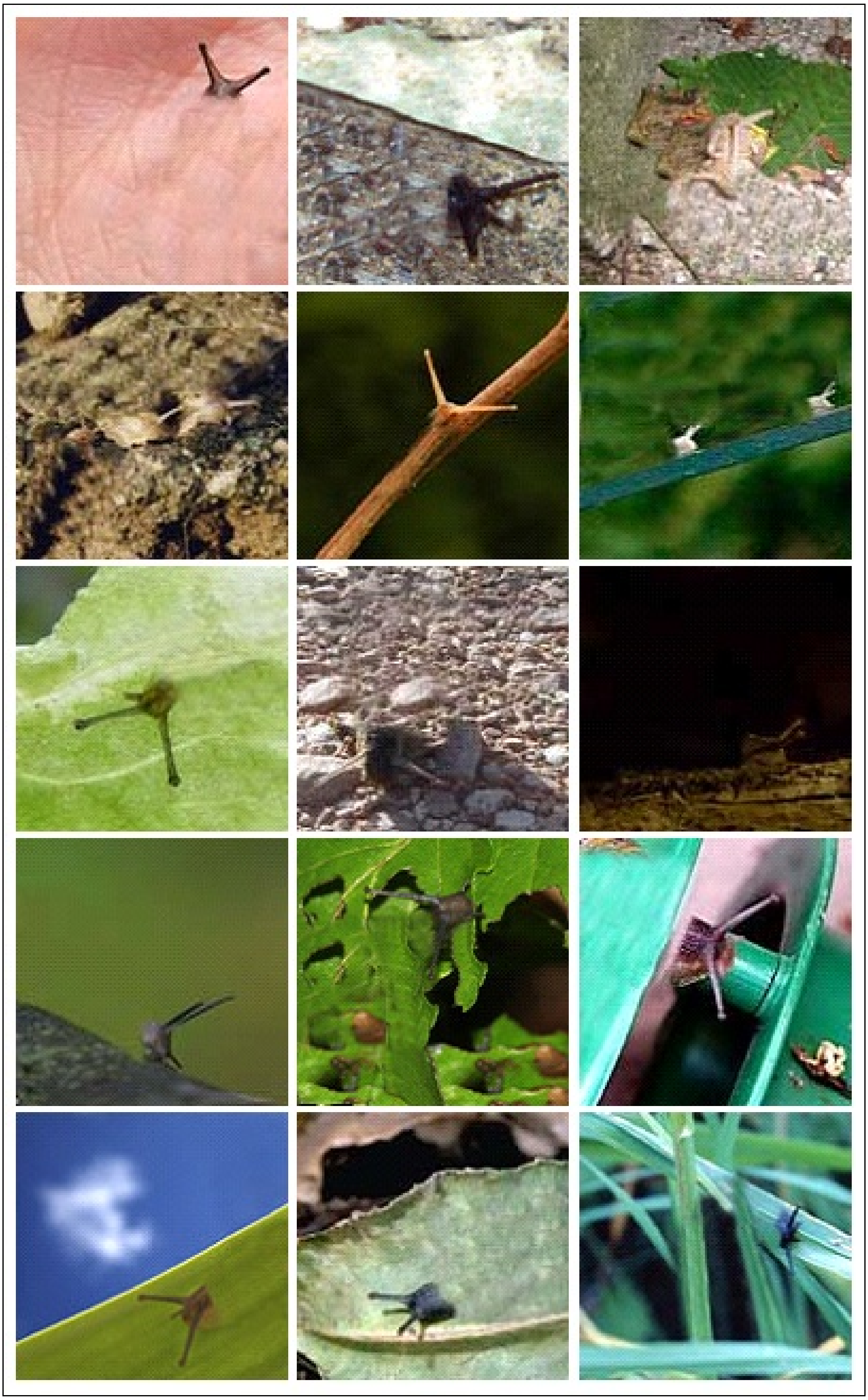

Figure A7. Examples of test stimuli showing heads that were shown to both subject groups in the Picture-Object Recognition Test.

Figure A8. Examples of test stimuli showing shells that were shown to both subject groups in the Picture-Object Recognition Test.

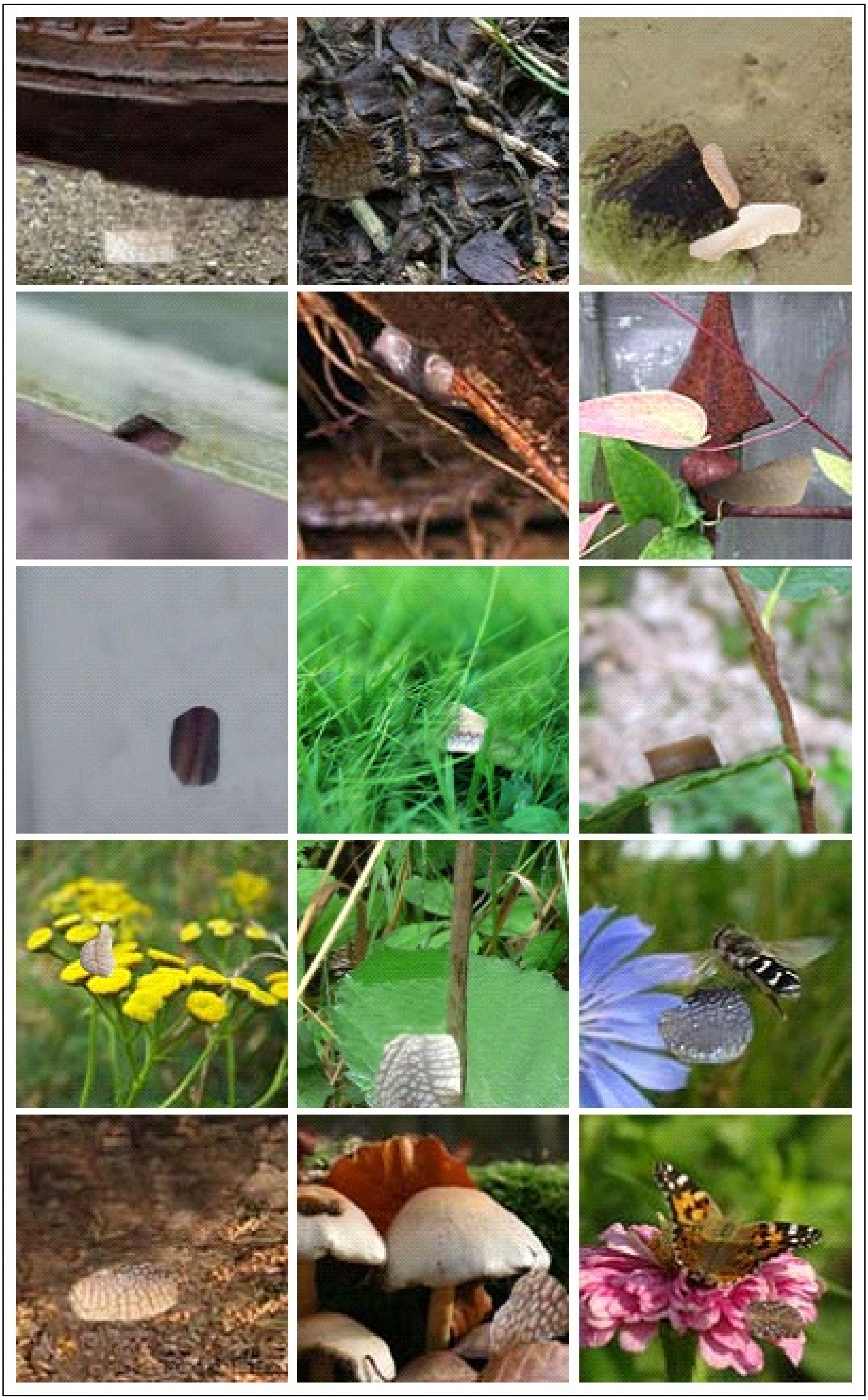

Figure A9. Examples of test stimuli showing patches of snail skin of arbitrary size and shape that were shown to both subject groups in the Picture-Object Recognition Test.

SUMMARY

Since the pioneering study by Herrnstein and Loveland (1964) it is known that pigeons are able to classify a variety of different objects into categories (e.g., on the basis of perceptual similarity) and that they are also able to generalize to novel class members. However, successful categorization does not necessarily mean that a subject also understands what a pictorial stimulus actually represents. It is hard to tell, whether the tested subjects have really understood that a depicted object "stands for" the real object (DeLoache, 1995; 2000). The question is, whether animals, just like humans, can recognize the relation between 2D-pictures and their 3D-referents.

The "*Complementary Information Procedure" (CIP)* introduced by Aust and Huber (2006) allowed for a distinction between representational insight and less advanced mechanisms of picture-object recognition. Pigeons trained to discriminate between pictures of (incomplete) humans and pictures without humans subsequently responded more to pictures of parts of a human figure that had been absent in the training stimuli than to pictures of non-representative patches of human skin. This suggests that the birds recognized the correspondence between the (incomplete) human figures shown in the training stimuli and live human beings, i.e., they recognized the missing parts shown in the test as representatives of real body parts.

In the current study I used the CIP to test the pigeons on a perceptual category they had no prior experience with, namely "snails". The birds were trained to discriminate between pictures of incomplete snails (i.e., bodies without the head or the shell, respectively) and pictures showing something else. Two out of eight subjects showed generalization to novel snail and non-snail pictures and could subsequently be subjected to the critical test for picture-object recognition. There, they were presented with pictures of the previously missing parts (UP) as well as with non-representative skin patches

(SK). As a control, they were also shown pictures of parts that had already been present in the training stimuli (SP). In contrast to the study by Aust and Huber (2006) the pigeons showed no difference in responding to UP and SK stimuli (i.e., peck rates to both types were similarly low). This indicated that they were not able to recognize the missing parts as belonging to the snail body, presumably because of their lack of experience with live representatives of the category snail. In conclusion, the present experiment supports the assumption that pigeons are able to transfer information about associations among real-life object parts to pictures thereof (Aust & Huber, 2006; 2010), that is, they are able to recognize the correspondence between familiar (or known) objects and pictures at a level beyond the discrimination of simple perceptual features.

ZUSAMMENFASSUNG

Seit der Pionierarbeit von Herrnstein & Loveland (1964) weiß man, dass Tauben in der Lage sind, eine Vielfalt von verschiedenen Objekten in ihre entsprechenden Kategorien einzuordnen (z. B. auf der Grundlage von Ähnlichkeit) und auch imstande sind, auf neue Kategoriemitglieder zu generalisieren. Jedoch bedeutet erfolgreiche Generalisierung nicht notwendigerweise, dass ein Versuchstier auch versteht, wofür ein bildlicher Stimulus steht. Es ist schwer zu sagen, ob die Versuchstiere wirklich verstehen, dass ein abgebildetes Objekt für das echte Objekt steht (DeLoache, 1995; 2000). Die Frage ist, ob Tiere, ebenso wie Menschen, die Beziehung zwischen zweidimensionalen Bildern und ihren dreidimensionalen Referenzobjekten erkennen können.

Die "*Complementary Information Procedure*" *(CIP)*, eine Methode, die von Aust und Huber (2006) eingeführt wurde, erlaubt eine Unterscheidung zwischen „repräsentativer Erkenntnis" (representational insight) und weniger anspruchsvollen Mechanismen der Bild-Objekt-Erkennung. Tauben, die trainiert wurden, zwischen Bildern mit (unvollständigen) Menschen und Bildern ohne Menschen zu unterscheiden, reagierten im darauffolgenden Test stärker auf Bilder von zuvor fehlenden Körperteilen als auf Bilder von nicht repräsentativen Hautteilen. Dies weist darauf hin, dass die Vögel einen Zusammenhang zwischen den (unvollständigen) Körperteilen und echten Menschen erkannten, d. h. sie erkannten die fehlenden Teile im Test als Vertreter von echten Körperteilen.

In der vorliegenden Studie verwendete ich die „Complementary Information Procedure" (CIP) mit einer Kategorie, mit der die Tauben keine vorherige Erfahrung hatten, nämlich der Kategorie „Schnecke". Die Tiere wurden trainiert, zwischen Bildern von unvollständigen Schnecken (d. h. ohne Kopf oder Haus) und Bildern ohne Schnecken zu unterscheiden. Zwei der insgesamt acht Versuchstiere zeigten auch Generalisierung zu neuen Schnecken- und Nichtschneckenbildern und konnten daher im kritischen Test für Bild-Objekt-Erkennung geprüft werden. Bei diesem wurden sie sowohl mit Bildern der zuvor fehlenden Teile (UP) als auch mit Bildern nicht repräsentativer Hautteile (SK) konfrontiert. Als Kontrolle wurden ihnen auch Bilder mit bereits aus dem Training bekannten Teilen (SP) gezeigt. Im Gegensatz zu der Studie von Aust und Huber (2006) zeigten die Tiere keinen Unterschied in der Reaktion auf die UP- und SK-Bilder (d. h., ihre Pickraten waren bei beiden Bildtypen ähnlich niedrig). Dies deutet darauf hin, dass die Tiere aufgrund ihres Mangels an der Erfahrung mit lebenden Vertretern der Kategorie „Schnecke“ nicht in der Lage waren, die fehlenden Teile dem Schneckenkörper zugehörig einzuordnen.

Die Ergebnisse dieses Experiments bestätigen also die Annahme, dass Tauben in der Lage sind, Information über Assoziationen zwischen den Teilen echter Objekte auf Bilder der selben Objekte zu übertragen (Aust & Huber, 2006; 2010), d. h. Tauben sind fähig, den Zusammenhang zwischen Teilen eines bekannten Objekts und den entsprechenden Teilen auf einem Bild jenseits der Unterscheidung einfacher perzeptueller Eigenschaften zu erkennen.

DECLARATION

Herewith I ensure that I wrote this Master´s Thesis independently using only the indicated sources and means for writing. For individual parts inferred from other publications, literally or according to the sense, references have been made within the text. The same applies to pictures, tables and figures.

Hiermit erkläre ich, dass ich diese Masterarbeit selbstständig und nur unter Verwendung angegebener Quellen und Hilfsmittel verfasst habe. Für einzelne Teile, die im Sinne oder Wortlaut aus anderen Publikationen entnommen wurden, sind im Text dementsprechende Referenzen angegeben. Dasselbe gilt auch für Bilder, Tabellen und Grafiken.

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Referee: Ao. Univ. Prof. Mag. Dr. Ludwig Huber