Published in final edited form as:
Psychol Sci. 2009 September ; 20(9): 1108–1117. doi:10.1111/j.1467-9280.2009.02430.x.

Conditions for face-like expertise with objects: Becoming a Ziggerin expert – but which type?

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Abstract

Faces are processed more holistically than other objects and are recognized efficiently at the individual level. Perceptual expertise individuating non-face objects can lead to the same hallmarks of face processing. Is this specifically a result of expertise individuating objects, or would any type of prolonged intensive experience with objects be sufficient? Two groups of participants were trained with artificial objects (Ziggerins). One group learned to rapidly individuate Ziggerins at the subordinate level. Another group learned rapid sequential categorizations at the basic level. Individuation experts showed a selective improvement at the subordinate level and an increase in holistic processing. Categorization experts only improved at the basic level without changes in holistic processing. Attentive exposure to objects in a difficult training regimen is not sufficient to produce face-like expertise. Rather, qualitatively different types of expertise with objects of a given geometry can arise depending on the type of training.

Keywords

Face Perception; Learning; Object Recognition; Visual Perception

INTRODUCTION

Debates about whether face processing is “special” or not center around whether hallmarks of face processing can also be found for objects of expertise. Generally, processing of faces and non-face objects differ in two important ways: First, faces are processed more holistically than other objects, in that it is more difficult to selectively attend to a single face part than an object part (e.g., Cheung *et al.*, 2008; Farah *et al.*, 1998; Gauthier & Tarr, 2002; Richler *et al.*, 2008a; Richler *et al.*, 2008b). Second, configural information about spatial relationships between parts is more important for face perception (e.g., Diamond & Carey, 1986; Gauthier & Tarr, 2002; Tanaka & Sengco, 1997). Some suggest that holistic and configural processing occur because they are innate properties of face perception or reflect early developmental constraints (McKone *et al.*, 2007). Others suggest that configural and holistic processing reflect perceptual styles and attentional strategies that can be learned through expertise with a category (Gauthier & Tarr, 2002). For example, a strategy to attend to all parts of an object (holistic processing) may be learned when configural relations between features are especially diagnostic of identity (Diamond & Carey, 1986; Le Grand *et al.*, 2004; Leder & Bruce, 1998, 2000; Mondloch *et al.*, 2002; Searcy & Bartlett, 1996).

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Holistic and configural processing can be observed for non-face objects with expertise. Training with novel objects (Greebles) has revealed small but significant increases in both configural and holistic processing (Gauthier & Tarr, 1997, 2002). Increases in holistic processing during the acquisition of Greeble expertise correlate with changes in the response of the fusiform face area (FFA) to these objects (Gauthier & Tarr, 1997). Expertise with real-world objects also increases holistic processing: Cars in a normal configuration are processed more holistically than cars in an unfamiliar configuration, with this effect directly related to an observer's level of car expertise (Gauthier *et al.*, 2003). These claims are not without debate, particularly on the appropriate task design and analyses used to measure holistic and configural effects (e.g., compare Robbins & McKone, 2006, and McKone & Robbins, 2007 with Cheung *et al.*, 2008, Gauthier & Bukach, 2007, and Richler *et al.*, 2008). But putting methodological debates aside, one critical prediction of the expertise account has yet to be tested: Is it specifically expertise at individuating objects within a visually homogeneous category that causes participants to rely on configural information and develop a more holistic processing strategy (Bukach *et al.*, 2006; Gauthier & Tarr, 1997)?

According to the expertise hypothesis, significant experience with novel objects but without an individuation requirement should not produce face-like configural and holistic effects. For example, consider a domain for which all literate humans acquire expertise – the orthographic characters of their language. For faces and other domains of expertise that require individuation, objects are categorized as quickly at the subordinate identity level as the more general basic level (Tanaka, 2001; Tanaka & Taylor, 1991); for most other objects there is a basic-level advantage (Rosch *et al.*, 1976). In contrast, expertise with Roman letters or Chinese characters requires basic-level categorization, ignoring variability due to font or handwriting (Gauthier *et al.*, 2006). Such expertise is associated with *greater* basic-level advantage compared to novice categorizers (Wong & Gauthier, 2007). A reduction in configural and holistic processing has also been shown with letter and character expertise (Ge *et al.*, 2006; Hsiao & Cottrell, in press; van Leeuwen & Lachmann, 2004; but see Pelli & Tillman, 2007; Simon *et al.*, 2007).

To date, there is little evidence that individuation training *per se* reduces the basic-level advantage and increases configural and holistic processing strategies. In fact, some evidence suggests that even mere exposure to objects can produce effects once thought to be the hallmark of face-like expertise (e.g., the N170 face-selective ERP potential, Peissig *et al.*, 2007; Scott *et al.*, 2006, 2008). Few studies have compared effects of different training regimens using the same objects. One found that generalization of rapid individuation skills to new exemplars of a trained category follows individuation training but not basic-level categorization training (Tanaka *et al.*, 2005). Another (Nishimura & Maurer, 2008) showed that individuation, but not basic-level categorization, of blob patterns resulted in higher sensitivity to metric differences in spatial relations among blobs. One issue is that these studies compared a difficult training regimen to a far-easier training, with little evidence of learning in the latter condition. Also, none of these previous studies examined whether different training regimens produced differential changes in holistic processing of the learned objects.

Here, we compared the effects of individuation and categorization training on the same set of novel objects, holding object geometry and testing tasks constant. Instead of using basic-level categorization as an easy control for mere exposure, we aimed to train categorization experts by modeling some key components of our experience with letters (Hsiao & Cottrell, in press; Wong & Gauthier, 2007). Specifically, an important portion of categorization training was devoted to rapid, sequential basic-level categorization of objects within a spatial array. This task was designed to mirror some of our experience with letter recognition when reading texts.

We also examined holistic processing and its sensitivity to object configuration, after training, using a composite task. The primary hypothesis is that expertise at individuating objects within a visually homogeneous category is required for participants to develop a holistic processing strategy specific to the trained configuration of parts; by contrast, experience categorizing at the basic level should be insufficient.

METHOD

Participants

Participants were 52 undergraduate students, graduate students, and staff at Vanderbilt University. Eighteen participants were assigned to the individuation training group (twelve females, age M=24.06, SD=5.92), 18 to the categorization training group (ten females, age M=23.33, SD=5.63) and 16 to a no-training control group (four females, age M=27.63, SD=3.74). All reported normal or corrected-to-normal vision. Participants were paid $12/hour.

Stimuli and Design

Seventy-two novel objects, called Ziggerins (see Figure 1) were created using Carrara 5 software (MetaCreations). There are six classes of Ziggerins, each defined by a unique part structure. Within each class, there are 12 styles, each defined by part variations of cross-sectional shape, size, and aspect ratio. The same style variations applied across all 6 classes. This combination of class and style is analogous to 6 different letters shown in 12 different fonts. A pilot card sorting study (n=13) revealed that novices easily recovered both class and style.

Procedure

Training Regimens—Each participant was trained with 36 Ziggerins (selection randomized across participants), with the remaining Ziggerins reserved for pretests and post-tests. Training occurred over ten one-hour sessions. The *categorization training group* learned to categorize the 36 Ziggerins into the 6 classes. The *individuation training group* learned individual names for 18 of the 36 Ziggerins, with the other 18 objects used as distractors. Two-syllable nonsense words (e.g., Xedo, Kimo) were randomly assigned as names for classes or individuals for each participant. Ziggerins were introduced progressively in sessions 1–3; sessions 4–10 used all Ziggerins (Table 1). For both training regimens, each training session included three tasks (described later). For all tasks, both speed and accuracy were emphasized and corrective feedback was provided. At the end of each training block, average accuracy and speed were displayed to participants. From session 4 onwards, to further motivate participants, a rank table was shown with their ten best blocks, providing encouragement to break their speed record while maintaining high accuracy. In all tasks (except matrix scanning, as described later), each Ziggerin spanned a visual angle of 3.8°.

Individuation training was similar to prior Greeble training (Gauthier & Tarr, 1997; Gauthier *et al.*, 1998). Each training session included three tasks: naming, verification, and matching. In *naming*, a Ziggerin was shown until a response was made (typing the first letter of its name). On 10% of trials, an unnamed object was shown, with the space bar the correct response. In *verification*, an individual name appeared for 1sec, followed by a Ziggerin after 200ms and shown until a response ("match" or "nonmatch") was made. On nonmatch trials, the distractor was another object from the same class or the target object with a modified part or a slight configural change. In *matching*, an individual name was shown for 1sec, followed by a blank screen for 200ms, and then two Ziggerins appeared side by side until a response was made indicating the location (left or right) of the match. On 25% of trials, neither Ziggerin was the target and the correct response was the space bar. Distractors were the same as in the verification task.

Categorization training was designed to teach participants names of Ziggerins at the class level and required them to rapidly categorize Ziggerins in the context of an array of other Ziggerins of the same style. Each training session included three tasks: naming, verification, and matrix scanning. *Naming* and *verification* were the same as above (with the distractor from a different class on nonmatch trials during verification). In *matrix scanning*, an array of 40 Ziggerins appeared (5 rows × 8 columns), covering a visual angle of 15°×26° (2.8°×2.8° for each Ziggerin). Participants were told: “The upper left object is your first target. Scan the matrix from left to right, top to bottom until you find your target. The next object in the matrix then becomes your new target. Keep scanning the matrix until you find this new target. Continue this process until you get to the end of the matrix. Press the space bar as soon as you get to the end. After pressing the space bar, type the first letter of the last target you were searching for." Within each matrix, all Ziggerins had the same style, so that the task required only categorization at the class level. Five to seven target shifts occurred within each matrix. Matrices were carefully generated with the following considerations: (1) each duplet and triplet combination occurred as frequently as every other to avoid any sequence learning, (2) each Ziggerin had an equal chance of being the final target, (3) all Ziggerins occurred equally often, (4) all styles were used equally often.

Pretest and Post-tests—The 36 untrained Ziggerins were used during testing. A sequential matching task was performed at pretest and post-test. To minimize participants’ initial experience with Ziggerins and maximize the difference between training groups, a composite task and a triplet matching task were only performed at post-test. To provide a baseline for the composite task, a group of novices was tested. Practice trials were provided for each task.

In *sequential matching*, the advantage of categorization at the basic over subordinate level was measured (Gauthier & Tarr, 1997; Tanaka, 2001; Tanaka & Taylor, 1991). Participants judged if two sequentially presented Ziggerins were same or different. On some trials, they judged same or different individuals; on other trials, they judged same or different classes. To demonstrate the meaning of a “class” to novices, a sheet with images of all Ziggerins was shown before the task and participants were told that objects within a row formed a class. A trial consisted of a fixation cross for 500ms, the first Ziggerin for 800ms, a pattern mask for 500ms, followed by the second Ziggerin displayed until a “same” or “different” response was made or for 5sec. A total of 12 blocks of 72 trials each were used, with alternating blocks of class or individual judgments. For individual blocks, same trials displayed identical objects; for different trials, distractors were different individuals within the same class. For class blocks, same trials displayed two different Ziggerins within a class; for different trials, distractors came from a different class and could be of the same or different styles. To encourage matching of objects and not images, one Ziggerin was always slightly larger than the other (three sizes were used: 3.2×3.2, 4.0×4.0, and 4.8×4.8 cm^2). Speed and accuracy were both emphasized and no feedback was given.

A variant of the *composite task* from the face recognition literature was used to measure holistic processing and its dependence on configuration (Cheung et al., 2008; Gauthier et al., 2003; Gauthier & Tarr, 2002; Richler et al., 2008a; Richler et al., 2008b); procedure details followed the face recognition studies, except for our use of Ziggerins. Composites were made by combining the top half and bottom half of Ziggerins within the same class but having different styles[1]. A trial consisted of a fixation cross for 500ms, the first composite for 400ms, a pattern mask for 3000ms with a cue bracket for the top (or bottom) part for the last 500ms of the mask, and the second composite (Figure 2). Participants indicated by key press if the top (or bottom) halves of the two composites were same or different within 1000ms (half were same trials). No feedback was given. The halves of the second composite were either aligned or misaligned (Figure 2).

Two variants of the composite task have been widely used. In one, which has been called a *partial design* (Gauthier & Bukach, 2007), the irrelevant part is always different, only "same" trials are analyzed and configural processing is defined by better performance matching relevant parts in a misaligned configuration. The version used here, called the complete design, allows the irrelevant part to be the same or different, deconfounding congruency between the two parts of the composite, and examines performance on both "same" and "different" trials, allowing certain measures that are not possible with the partial design (e.g., see Cheung *et al.*, 2008; Gauthier & Bukach, 2007; Richler et al., 1998, 2008a, 2008b; see also Farah et al., 1998; Wenger & Ingvalson, 2002). We used the complete design because of arguments fully articulated in our previous articles. As such, the target parts (to which participants responded) and the distractor parts (to be ignored) of the two composites were either congruent in response (both parts same or different, Figure 2B) or incongruent (one part the same, the other different, Figure 2A). Either top and bottom parts could be targets (randomized across half of the trials). The Alignment × Congruence × Target Part × Same/Different design resulted in 16 conditions and each condition had 18 trials (288 trials total). Trials from the various conditions were randomized and presented in four blocks of 72 trials. We expected a cost of selective attention to part of a Ziggerin, indexed by worse performance on incongruent than congruent trials. Holistic processing was defined as sensitivity to part configuration and indexed by the selectivity of the congruency effect to an aligned configuration of parts, i.e., the alignment × congruency effect. Following previous work, we examined costs to both discriminability and response times; costs have been previously revealed in one, the other, or both measures (Cheung *et al.*, 2008; Gauthier et al., 2003).

A *triplet recognition* task aimed to measure perceptual fluency with short sequences of three Ziggerins. Prior work on expert perception of Roman letters and Chinese characters (Gauthier et al., 2006; Wong & Gauthier, 2007) revealed both rapid basic-level categorization of character arrays and font regularity effects. We hypothesized that after categorization training, analogous rapid categorization and style regularity effects might be observed. A trial consisted of a pattern mask for 1sec, three target Ziggerins presented side-by-side for a calibrated duration (see below), followed by a 200ms mask. Then, at each of the three locations, two Ziggerins were presented, one above the other, and participants selected studied targets from left to right. Accuracy was emphasized and no feedback was provided. The three objects were always in different classes but were either the same style or mixed styles, and the styles of the alternatives always matched those studied targets. A key measure was the calibrated duration of the initial Ziggerin presentation. A staircase procedure over 10 blocks of 12 trials was used to find the presentation duration of the three study Ziggerins that led to 2.25 Ziggerins recognized. Presentation duration started at 600ms and changed according to participants' performance after each block, with step size changing gradually from 220ms at 660ms or above to 20ms at 100ms or below.

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[1] Half of the trials in this task used composites made from two Ziggerins from different classes. These trials did not result in significant congruency effects for either training group and are not reported here. The large difference in shape between classes likely facilitated selective attention to the cued part.

RESULTS

Training Performance

We cannot directly compare overall training performance between groups because the training tasks were different. The training tasks are really just vehicles for encouraging differences in processing and/or representation, not a focus of investigation in and of themselves. Both groups showed accuracy near ceiling throughout training (i.e., well over 90% in all tasks and all sessions) with significant increases observed only in some of the tasks. The constant accuracy in some tasks may be surprising, especially for the early training sessions, but recall that additional classes and styles were gradually added over the first three sessions. Significant improvement in speed was observed in all training tasks (Figure 3). We do not report the statistical analyses across the six training tasks here, but the confidence intervals in the figure are those relevant to the significant learning effects. Again, when inspecting Figure 3, recall that additional named Ziggerins were added over the first three session; this likely contributes to the plateau apparent in the individuation training group.

Sequential matching: The basic-level advantage

At pretest, both groups were faster at matching by class (the basic-level) than by individual, but training produced opposite effects on the two groups (Figure 4). Individuation training *reduced* the basic-level advantage whereas categorization training *increased* the basic-level advantage. A Group (categorization vs. individuation) × Testing Session (pretest vs. post-test) × Level of Categorization (class vs. individual) ANOVA showed a main effect of Testing Session [$F(1,34)=94.13$, $p \leq .0001$[2], $\eta_p^2=.734$] and a main effect of Level [$F(1,34)=41.43$, $p \leq .0001$, $\eta_p^2=.549$]. Most importantly, there was a three-way interaction, confirming that the two groups displayed different changes in performance across class-level and individual-level judgments after training [$F(1,34)=4.00$, $p=.054$, $\eta_p^2=.105$]. Separate ANOVAs revealed a Testing Session × Level interaction for the individuation group, indicating a significant reduction of the class-level advantage after training [$F(1,17)=6.34$, $p=.022$, $\eta_p^2=.272$]. Despite a numerical increase in the class-level advantage for the categorization group, this interaction was not statistically significant [$F(1,34)=1.02$, $p=.326$]. However, Scheffé tests ($p<.05$) showed that the categorization group was faster at the class level than the individuation group after but not before training. Accuracy was near ceiling (>91%) before and after training.

Composite Task: Configural and holistic processing

Data from two participants in the individuation group and four in the categorization group were discarded because of low accuracy (<57%; none were excluded from the control group). As seen in Figures 5, sensitivity (*d'*) revealed a significant effect of congruency without a significant difference between training groups; unfortunately, the visible trend toward an interaction between congruency and alignment did not reach statistical significance. However, response times did show significantly different patterns between groups, with the individuation group showing a congruency effect for aligned stimuli but not for misaligned stimuli. Response times for the two training groups were compared in a Group (categorization vs. individuation) × Congruency (congruent vs. incongruent) × Alignment (aligned vs. misaligned) ANOVA. All two-way interactions were significant [Group × Congruency: $F(1,28)=3.75$, $p=.063$, $\eta_p^2=.118$; Group × Alignment: $F(1,28)=4.47$, $p=.044$, $\eta_p^2=.138$; Congruency × Alignment: $F(1,28)=3.90$, $p=.058$, $\eta_p^2=.122$]. The most theoretically important finding, however, was the significant three-way interaction

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[2] A significant result at $p<.05$ corresponds to a probability of replication (p_{rep}) .916 or higher (Kileen, 2005).

[*F*(1,28)=4.07, *p*=.053, $\eta_p^{\ 2}$=.127]. Separate ANOVAs revealed a significant Congruency × Alignment interaction only in the individuation group [*F*(1,15)=6.12, *p*=.026, $\eta_p^{\ 2}$=.290]. Scheffé tests (*p*<.05) showed that for the individuation group, responses were faster on congruent than incongruent trials for aligned but not misaligned trials. Figure 5 also displays data from a separate group of 16 untrained control participants. While there was a significant congruency effect in *d*' for the control group [*F*(1,15)=18.845, *p*=.0006, $\eta_p^{\ 2}$=.556], congruency did not interact with alignment (*p*>.22).

The interaction between alignment and congruency found after individuation training is very similar to the hallmark finding with faces (e.g., Richler *et al.*, 2008b). For faces, a congruency effect that interacts with alignment in both sensitivity and response time is typically found. For non-face experts trained with Greeble objects in the laboratory, an interaction between congruency and alignment has been observed in response times (*p*=.06, Gauthier et al.,1998), while in extant car experts, a similar interaction was observed in sensitivity (Gauthier et al., 2003). After laboratory training for a limited number of sessions, there can be quite a bit of heterogeneity in the amount of expertise various subjects have acquired, so perhaps it is not surprising that behavioral effects in the composite task after days of Ziggerin training might be weaker than what is typically observed after a lifetime of experience with faces. As such, significant behavioral effects are seen in one dependent measure, while only nonsignificant trends are seen in the other dependent measure. What is clear is that for non-face novice objects, no interaction between congruency and alignment has been observed in past work and sometimes a congruency effect is observed without any interaction with alignment (Richler *et al.*, in press). This is precisely what we observed after categorization training. While congruency effects can be observed with non-face novice objects for a variety of reasons (Richler *et al.*, in press), an interaction between alignment and congruency like that obtained after individuation training is a hallmark of face processing not found for non-face novice objects (e.g., Richler *et al.*, in press; Robbins & McKone, 2007).

Triplet recognition: An advantage for categorization training

The duration threshold acquired during triplet recognition is used here as an index of perceptual fluency for rapidly categorizing objects within a short string of Ziggerins. After training, the categorization group required a significantly shorter presentation duration than the individuation group to achieve the 2.25-Ziggerin recognition level [193ms vs. 294ms, for categorization and individuation, respectively, *F*(1,35)=6.93, *p*=.013, $\eta_p^{\ 2}$=.165)].

DISCUSSION

It is meaningful to talk about kinds, not merely degrees, of perceptual expertise with objects (Wong & Gauthier, 2007). With the same set of objects, but different training regimens, two groups of perceptual experts demonstrated different hallmarks of expertise when tested on new exemplars of the trained object categories. As in prior work with experts at individuation trained in the real world (Busey & Vanderkolk, 2005; Gauthier et al., 2003) or in the laboratory (Gauthier & Tarr, 1997; Gauthier et al., 1998; Scott et al., 2006, 2008), individuation training reduced the basic-level advantage and increased holistic processing. These effects were not observed in categorization experts, who instead became faster at basic-level judgments.

A unique feature of the current study is that that factors like mere exposure, attention, and effort are insufficient to account for the face-like expertise effects found after individuation training. Other studies have shown effects of individuation training relative to other training equated for exposure (Nishimura & Maurer, 2008; Scott et al., 2006, 2008; Tanaka et al., 2005). But in those cases, not only was the comparison training task far easier but there was no evidence that the control group learned anything qualitatively different from the individuation training group. The difference between groups was only a matter of degrees and participants in the comparison training could not be claimed to be “experts” in any way. In contrast, our categorization experts were faster than our individuation experts at basic-level categorization and showed increased perceptual fluency in the triplet recognition task. These selective advantages of categorization training could not have occurred if categorization training recruited the same strategies as individuation training, but to a lesser degree. The requirements of guided visual search and speeded basic-level categorization in an array, unique to our experiment, may have caused a different perceptual strategy from that after individuation training.

Our individuation and categorization training regimens differed in multiple aspects, but surely not any more than in the actual acquisition of face-like and letter-like expertise. Our goal was not to make specific inferences about *which* particular aspect of training produced our effects. To know which particular aspect was critical, we would need to systematically examine the effects of each training component and their various combinations. Our goal, instead, was to demonstrate that two different kinds of expertise *can* be acquired for the same set of objects.

Our training effects were smaller in magnitude than those reported in other experiments with novel objects (e.g., Gauthier & Tarr, 1997) and with real-world experts (e.g., Gauthier et al., 2003). Given the differences between this experiment and earlier work, this may not be surprising. Prior face-like training with a homogeneous set of Greeble objects required between 7 and 10 hours for the disappearance of the basic-level advantage (Gauthier & Tarr, 1997; Gauthier et al., 1998). All Greebles share a common part configuration, constituting one basic-level class. In contrast, expertise effects would not be expected to generalize across different classes of Ziggerins, which means that our 10 total hours of training amounts to less than 2 hours per class. It is reasonable to expect that longer training with Ziggerins would increase the effects obtained here. More importantly, our results demonstrate that the qualitative markers of face-like expertise appear in non-face object categories that clearly do not have any face geometry, and after only about 1,500 training trials per category. While limited laboratory training in artificial domains is unlikely to produce expertise of the same magnitude as that acquired in the real world, hallmarks of face-like expertise do not require 10 years, or even 10 hours, of experience to emerge (Gauthier & Tarr, 1997; c.f. Diamond & Carey, 1986).

Acknowledgments

This research was supported by grants from the James S. McDonnell Foundation and the National Science Foundation (to I.G. and T.J.P) and the National Eye Institute (to I.G.). The authors thank all the members of the Perceptual Expertise Network (funded by JSMF), as well as Gordon Logan, Tom Carr, and Donald Compton for valuable discussion. We thank Jenn Richler and Mike Mack for suggesting the name “Ziggerins”.

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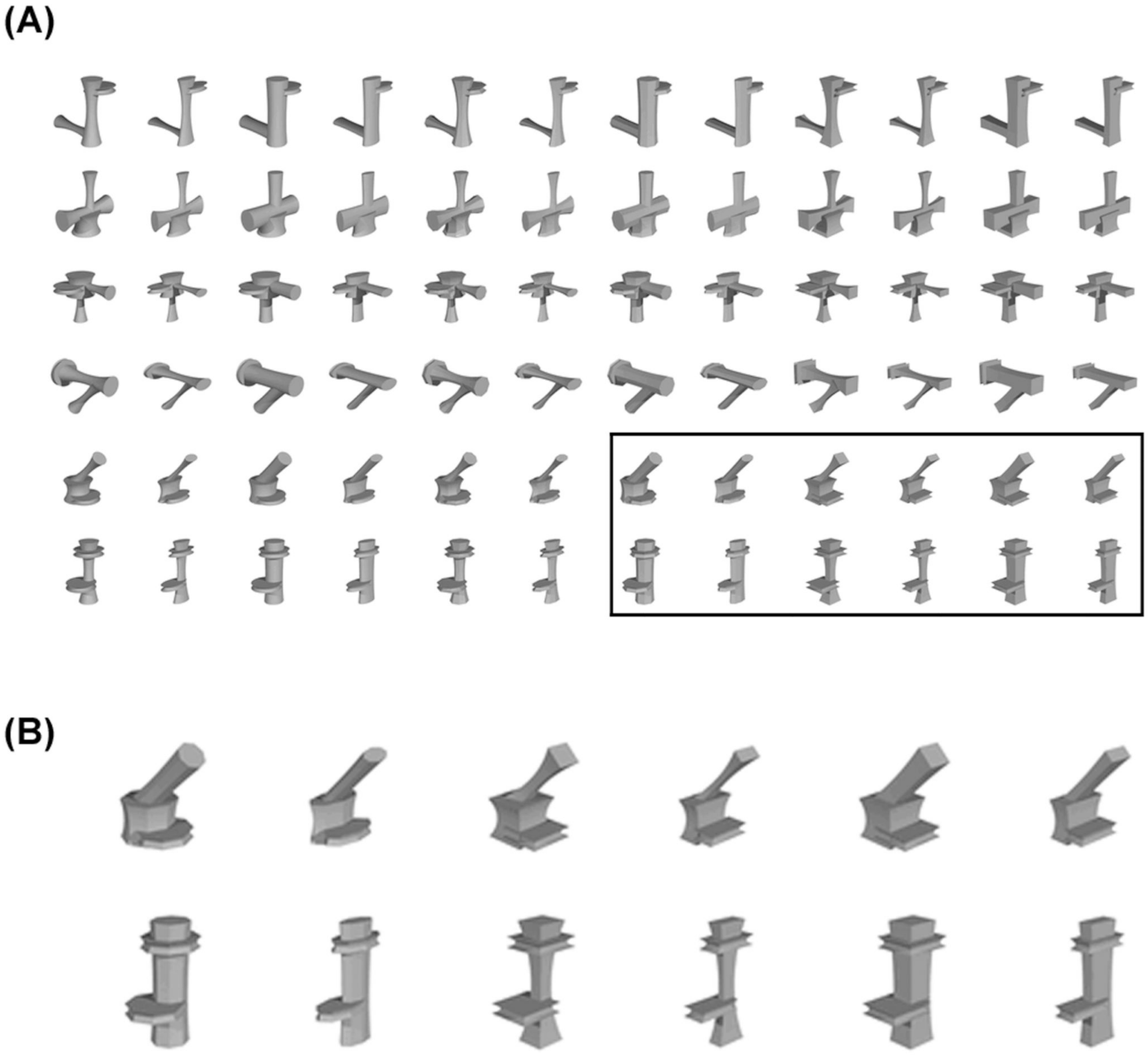

Figure 1.

The artificial objects (Ziggerins) used in the experiment. (A) The whole Ziggerin set. The rows correspond to the six classes, each with a unique set of parts and structure. The columns correspond to the 12 styles, each formed by parts with different cross-sectional shapes, aspect ratios, and size changes. (B) A subset of the Ziggerins magnified for visualization.

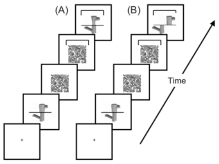

Figure 2.

Two example trials of the composite task. Both trials require matching the tops. On the left is a “different” trial, with the top and bottom aligned in the test display. It is an incongruent trial because the tops are different but the bottoms are the same. On the right is a “same” trial, with the top and bottom misaligned in the test display. It is a congruent trial because both the tops and the bottoms are the same.

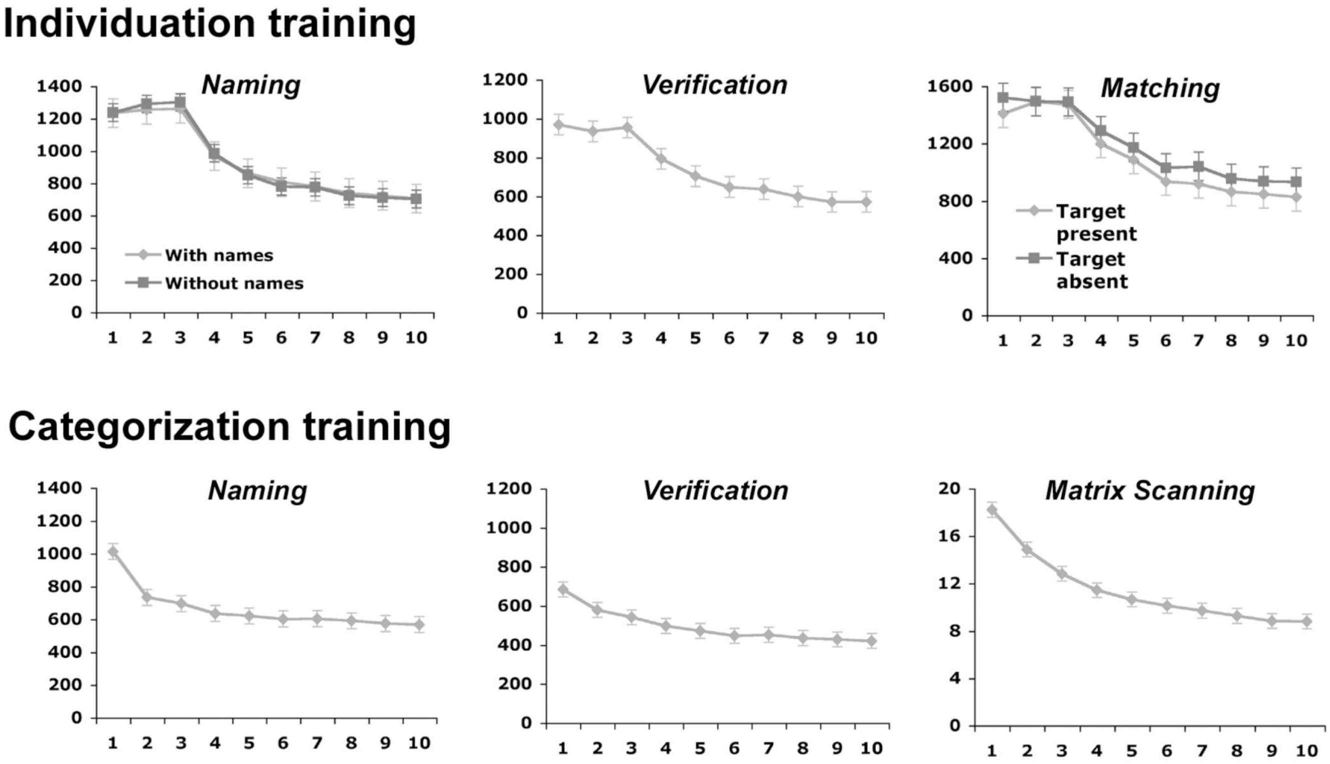

Figure 3.

Response times (in sec for matrix scanning and ms for others) for all training tasks across sessions. Error bars represent the 95% confidence intervals for the session effect.

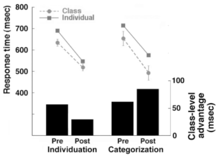

Figure 4.

Performance in the sequential matching task. Lines represent the response times and bars represent the class-level advantage (response times for individual judgment minus those for class judgment). Error bars represent the 95% confidence intervals for the class vs. individual judgment effect.

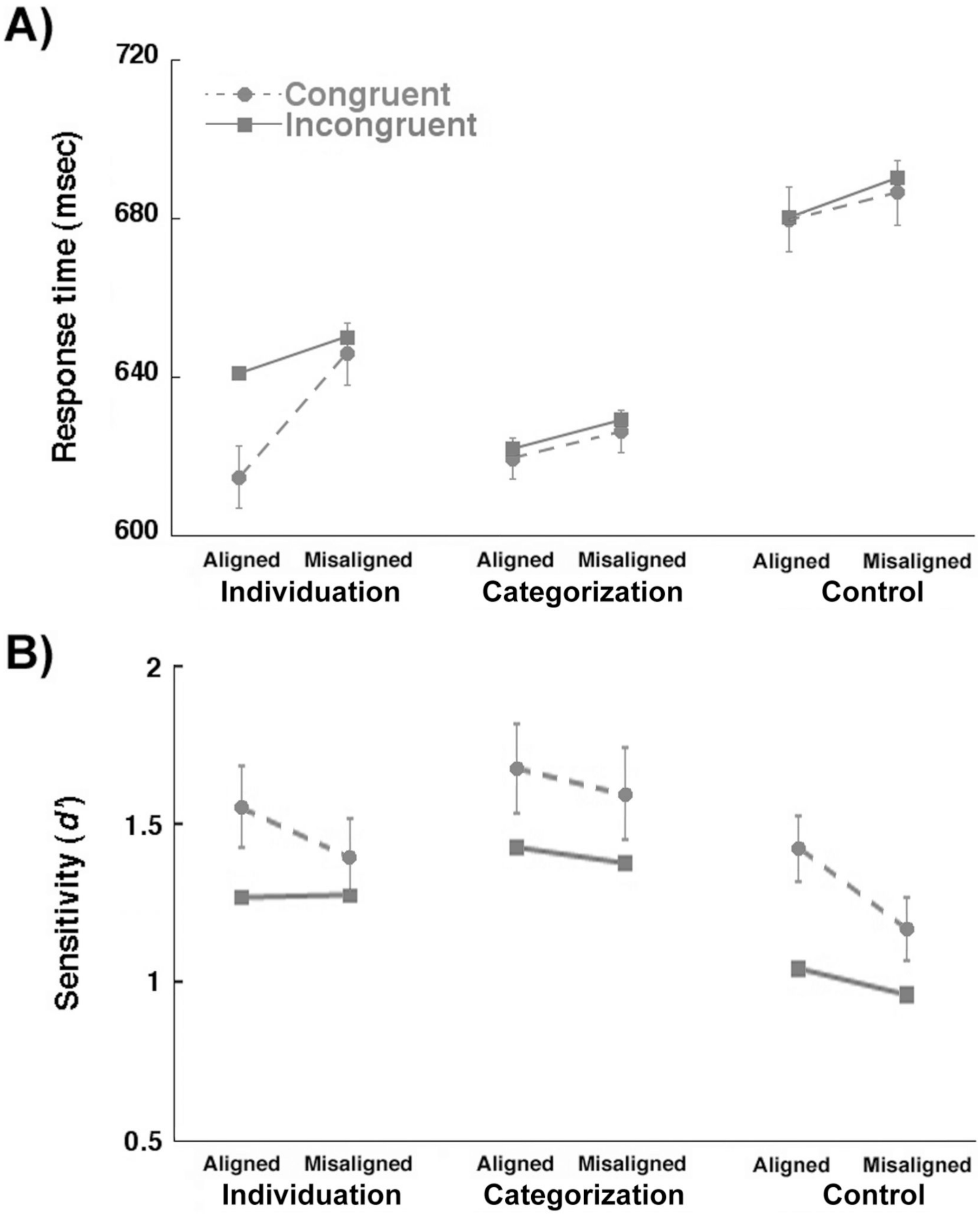

Figure 5.

Response times and sensitivity measures (*d*') in the composite task. Error bars represent the 95% confidence intervals for the congruent vs. incongruent trial effect.

Table 1

Training procedure across the ten sessions. For individuation training, two classes of Ziggerins were presented in Session 1, with two more classes introduced in Session 2, and the final two classes included from Session 3 onwards. For categorization training, two styles of Ziggerins were presented in Session 1, with two more styles introduced in Session 2, and the final two styles included from Session 3 onwards. Because the naming and verification tasks were relatively easy for the categorization group, from Session 4 onwards the there were additional matrix scanning trials presented.

Individuation training		**Categorization training**	
Trials per session	**Task**	**Trials per session**	**Task**
Session 1 (12 Ziggs)		Session 1 (12 Ziggs)	
360	Naming	360	Naming
288	Verification	288	Verification
288	Matching	84	Matrix scanning
Session 2 (24 Ziggs)		Session 2 (24 Ziggs)	
360	Naming	360	Naming
288	Verification	288	Verification
288	Matching	84	Matrix scanning
Session 3 (36 Ziggs)		Session 3 (36 Ziggs)	
360	Naming	360	Naming
288	Verification	288	Verification
288	Matching	84	Matrix scanning
Sessions 4–10 (36 Ziggs)		Sessions 4–10 (36 Ziggs)	
360	Naming	216	Naming
288	Verification	216	Verification
288	Matching	112	Matrix scanning