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The visual basis of category effects in object identification: Evidence from the visual hemifield paradigm

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Abstract

The basis for the category specific living things advantage in object recognition (i.e., faster and more accurate identification of living compared to nonliving things) was investigated in two experiments. It was hypothesised that the global shape of living things on average provides more information about their basic level identity than the global shape of nonliving things. In two experiments subjects performed name–picture or picture–name verification tasks, in which blurred or clear images of living and nonliving things were presented in either the right or the left visual hemifield. With blurred images, recognition performance was worst for nonliving things presented to the right visual field/left hemisphere, indicating that the lack of visual detail in the stimulus combined with a left hemisphere bias toward processing high frequency visual elements proved detrimental for processing nonliving stimuli in this condition. In addition, an overall living things advantage was observed in both experiments. This advantage was considerably larger with blurred images than with clear. These results are compatible with the global shape hypothesis and converge with evidence using other paradigms.
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1. Introduction

Participants in object identification experiments frequently display a relative advantage or disadvantage in the processing of objects belonging to a specific category or domain (see e.g., Capitani, Laiacona, Barbarotto, & Trivelli, 1994; Gerlach, 2001). Specifically, in well-controlled experiments, objects belonging to the domain of living things are identified faster and more accurately than nonliving objects in basic level identification tasks (e.g., Gerlach, 2001; Laws, 2000; Laws & Neve, 1999; Låg, 2005). The present work examines the possibility that the informativeness of the visual representations of objects, in particular the statistical differences in the informativeness of objects' overall global shape, may differ according to category and in turn play a causal role in these category specific effects.

Thus, in the present study, we manipulated the amount of available visual detail in object stimuli images. In addition, we lateralised these stimuli to each visual hemifield, or cerebral hemisphere, based on the account of cerebral lateralisation, which states that the left hemisphere (LH) is biased in its perceptual processing toward local/high spatial frequency visual elements, and that the right hemisphere (RH) is biased toward global/low frequency elements (e.g., Sergent, 1982).

1.1. The living things advantage and a possible explanation

Although previous studies of category specific effects in subjects without brain injury have reported a

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disadvantage for living things compared to nonliving things/artefacts (Capitani et al., 1994; Gaffan & Heywood, 1993; Humphreys, Riddoch, & Quinland, 1988; Lloyd-Jones & Humphreys, 1997), more recent experiments, using sets of stimuli that are better matched across category on potentially confounding variables such as concept familiarity and visual complexity, reveal the opposite asymmetry; that is, more accurate and faster identification of living things than of nonliving things (Gerlach, 2001; Laws, 2000; Laws & Neve, 1999; Låg, 2005).

At present, this living things advantage in visual recognition is without an established explanation. Some researchers have, however, suggested candidates for its possible causes. Laws and Neve (1999), for instance, suggest that exemplars within living things basic level categories tend to be more structurally similar to each other (e.g., any given horse resembles any other horse to a relatively high degree) than exemplars within nonliving categories (consider for instance the variety of shapes that different chairs can have). To the extent, therefore, that visual structure is reflected in the overall global shape of a visual stimulus and that visual recognition relies on global shape, nonliving things will be penalised because of their higher "intra-item representational variability" (Laws & Neve, 1999, p. 1268) . Indeed, the observed living things advantage has typically emerged under experimental conditions where reliance on global shape seems likely, for instance with brief stimulus exposure (Laws & Neve, 1999; Låg, 2005), or peripheral stimulus presentation (Gerlach, 2001). Gerlach (2001) has proposed a similar explanation, suggesting that the higher within-category similarity of living things results in their global shapes revealing more of their identity than the global shapes of non-living things.

Unfortunately, this emphasis on the role of global visual shape of objects in the living things identification advantage has received little direct empirical support. However, a recent study by Lloyd-Jones and Luckhurst (2002) provides suggestive results. In this experiment, participants performed an object decision task (i.e., deciding whether an object is real or not) on non-objects from the Kroll and Potter (1984) set and living and nonliving objects from the Snodgrass and Vanderwart (1980) set. In one condition, the stimuli had their interior areas filled in with black, thus essentially providing only the object's silhouette, whereas in the other condition the objects were presented as normal line-drawings complete with internal details. There was a general advantage for living things, but this advantage was significantly larger for the silhouettes. Thus, apparently, the identification of nonliving things can be negatively affected more easily than the identification of living things when only silhouette information is available to the observer. Lloyd-Jones and Luckhurst (2002) suggested that there is less useful information in nonliving things' outline contours.

An experiment by Vanucci, Viggiano, and Argenti (2001) also provides support for the special role of the global shape of living things. Their participants identified images of living and nonliving objects. These images were spatially filtered at nine different levels of resolution. This made it possible to determine the identification threshold for each of three categories. Results showed that animals were on average identified at a lower level of resolution than tools and vegetables, indicating that the information provided by the global shape of animals reveals more of their identity, whereas the global shape of tools is less helpful to their identification. However, in this experiment, stimuli were not matched across category for potentially confounding variables like familiarity and complexity, making interpretation of the results less straight forward.

Furthermore, evidence has accumulated that outline shape and configuration information of objects plays an important part in object recognition in general. In particular, the work of Hayward and colleagues (Hayward, 1998; Hayward, Tarr, & Corderoy, 1999; Keane, Hayward, & Burke, 2003) demonstrates that recognition of objects composed of simple volumetric components, when viewed across depth rotations, is no worse for silhouettes than it is for shaded images, and that changes in outline shape predict changes in recognition performance. Thus, to the extent that outline or global shape is crucial information for the object recognition system, it is likely to play a part in any category specific effects observed in recognition experiments.

1.2. Visual scale in the cerebral hemispheres

There is by now a substantial amount of evidence indicating that one of the more fundamental processing differences between the two cerebral hemispheres concerns the dimension of global versus local visual information, or low versus high spatial frequencies (Ivry & Robertson, 1998). Evidence comes from a number of different sources. Early case studies of patients with so-called constructional apraxia demonstrated that damage to the posterior portions of the right cerebral hemisphere tends to disrupt patients' reproduction of the global configuration of images (e.g., the way parts of a figure or map relate to one another; Black & Strub, 1976; Gainotti & Tiacci, 1970; McFie, Piercy, & Zangwill, 1950), while left hemisphere damage tends to lead to difficulties with reproducing the fine visual details of the same images (Black & Strub, 1976; Gainotti & Tiacci, 1970; McFie & Zangwill, 1960). Later results from research with brain-bisected patients converge with these findings. Generally, drawings executed by the left hand tended to preserve the overall structure of the figures to be copied, while in drawings executed by the right hand, the configuration of the figure is poorly copied, often despite a relative richness of detail (Gazzaniga, 1970).

The findings from constructional apraxia and split-brain patients cited above may be construed as having more to say about the spatial control of motor operations than about visual perception. Research exploiting the so-called hierarchical stimuli paradigm, where global figures, usually letters or simple geometrical forms, are composed of smaller figures of the same type (Navon, 1977), is more clearly in the domain of visual perception and memory. In these studies the participants' ability to identify or remember the global configuration and the local elements is assessed. Studies using normal subjects (Fagot & Deruelle, 1997; Martin, 1979; Robertson, Lamb, & Zaidel, 1993; Sergent, 1982; Van Kleeck, 1989), patients with lateralised brain damage (Robertson & Delis, 1986) and brain-bisected patients (Robertson et al., 1993) all indicate that the right hemisphere is biased toward global information and that the left hemisphere does not show this bias, or that it is even biased toward local information.

It has been argued that there is a close relationship between the global/local dimension of visual stimuli and the information carried by low versus high spatial frequencies (Hughes, Nozawa, & Kitterle, 1996). Indeed, the cerebral hemispheres do seem to be biased toward different frequencies as well, as originally suggested by Sergent (1982). For instance, in a series of studies by Kitterle et al. (Christman, Kitterle, & Hellige, 1991; Kitterle, Christman, & Hellige, 1990; Kitterle, Hellige, & Christman, 1992) subjects identified wide (low spatial frequency) sinusoidal gratings faster when these were presented in the left visual field (right hemisphere), whereas narrow (high spatial frequency) gratings were identified faster in the right visual field (left hemisphere).

2. Experiment 1

In Experiment 1, we tested the hypothesis that global shape is more informative with regard to identity for living things than for nonliving things by means of the visual half field paradigm. Picture stimuli in this experiment were blurred, so that the local/high frequency aspects of the objects' visual representations were more attenuated relative to the global/low frequency ones. A name–picture verification task was used, in which participants had to decide whether a picture matched a previously presented verbal label.

Given the previous findings of a living things advantage in normal object identification (Gerlach, 2001; Laws, 2000; Laws & Neve, 1999; Låg, 2005), we expected to find an overall advantage for living things. As previously mentioned, the living things advantage has typically been observed under presentation conditions that presumably hinder the extraction of visual detail from the stimuli (e.g., very brief or peripheral presentation of the stimuli). As the present experiment used both brief

and peripheral presentation, we should be able to observe the living things advantage. In addition, because blurring of the visual stimuli in this experiment further obscured local visual detail, this category specific effect was expected to be further enhanced.

Second, we expected identification to be less effective for the nonliving things in the right visual field (RVF)/LH than any other condition, given the left hemisphere's bias toward local visual aspects. This bias, combined with the hypothesised relative lack of useful information in the global shape of nonliving things, should strain the identification process. Conversely, and from the same logic, the combined influence of the higher information content of the global shapes of living things and the right hemisphere bias toward lower spatial frequencies, led us to expect more effective identification of the living things in the left visual field (LVF)/RH than any other condition. For the two remaining conditions, we should see intermediate levels of efficiency. In these conditions identification will likely be facilitated by either a hemispheric processing bias toward low frequency global aspects (in the nonliving-LVF/RH condition) or by the higher informativeness of the objects' global shapes (in the living-RVF/LH condition). At the same time, identification will likely be hampered by a relative lack of information provided by the objects' global shapes (in the nonliving-LVF/RH condition) or by a hemispheric processing bias toward higher frequency local aspects (in the living-RVF/LH condition).

2.1. Method

2.1.1. Participants

The participants were 48 unpaid volunteers (28 women and 20 men with a mean age of 23.5 years) recruited on the campus of the University of Tromsø. All were students at the university, and all of them were unaware of the specific purpose of the experiment. All participants were right-handed by self-report, native speakers of Norwegian, and had normal or corrected to normal vision.

2.1.2. Design, apparatus, and stimuli

For this experiment, we used a 2 (RVF/LH versus LVF/RH) by 2 (living versus nonliving objects) within-group design. The experiment was controlled by a Hewlett Packard portable computer with a 15 in. (38.1 cm) screen. Stimuli were presented and responses recorded using SuperLab software.

Stimuli consisted of 48 realistic drawings of objects (24 living and 24 nonliving things) selected from a larger set of a 100 pictures that were taken from a variety of visual dictionaries. The pictures were selected to represent six different categories with eight objects in each category. The categories were animals, fruit, vegetables, vehicles, tools, and kitchen utensils. A list of the picture

names is provided in Appendix A. Twenty independent subjects rated the pictures on several variables in a pilot study. Importantly, the pictures were equated across object domain on a number of potentially confounding variables. There were no significant average differences between living and nonliving things (all $t < 1.2$, all $p > .24$) on concept familiarity, visual complexity and name agreement (ratings were obtained using the same procedures as Snodgrass & Vanderwart, 1980), visual familiarity (ratings obtained using the procedures of Laws & Neve, 1999), or rated age of acquisition (ratings obtained using the procedures of Gilhooly & Logie, 1980).

The pictures were scanned to a resolution of 75 dpi and edited by use of commercially available software (Adobe Photoshop 4.0 LE) in the following manner: Any background in the pictures was removed, so that all objects appeared on a uniform white background. All objects were adjusted in size so that their longest axis fitted just within a frame of 10×10 cm. The pictures were then reduced to grey-scale images. All pictures were adjusted in brightness and contrast so that they were approximately equally dark (i.e., objects appearing in relatively light grey were darkened, and vice versa). This was performed by reading off greyscale values (in Adobe Photoshop) for the area covered by the picture, and approximating an average value of 50%. The pictures were then blurred using a Gaussian filter with a radius of seven pixels, thus attenuating mainly the local visual detail. Each picture was also copied and "flipped" 180° horizontally so that the same part of the picture could be faced toward fixation, regardless of whether the picture was presented in the left or right visual field. Samples of the stimuli are shown in Fig. 1. During presentation a picture subtended approximately 8° of visual angle with it's nearest edge at about 4° to the right or left of central fixation. All objects were presented in what were judged by the authors to be canonical orientations. Also, half of the living and half of the nonliving objects with what might be considered diagnostic parts (e.g., animals with

heads, or tools with a characteristic looking part, such as a hammer) were presented with this part toward the central fixation. The other half of these objects was presented with the diagnostic part away from central fixation.

2.1.3. Procedure

The pictures were arranged in four blocks of 56 trials, of which the first eight trials in each block were practice trials showing objects not included in the experiment. Each object appeared once in each block. Objects were shown once with a matching label in the left visual field, once with a matching label in the right visual field, once with a mismatching label in the left visual field, and once with a mismatching label in the right visual field. Mismatching names were drawn randomly from the other object labels in the same domain (living or nonliving). Trials were randomly allocated to blocks such that each block contained an equal number of positive, negative, RVF and LVF trials. (This means that for some of the items that were presented with a mismatching label, the item that was correctly matched to that label was presented in the same block. This occurred for roughly 50% of the labels in a block.) Trials within a block were presented in a different random order for each participant. The order of presentation of the blocks was completely counterbalanced across participants.

A trial proceeded as follows: (i) A fixation cross in the centre of the screen, which remained for 500 ms and was then replaced by (ii) an object label (matching or mismatching the following picture). This remained on screen for 1700 ms. (iii) A picture was then presented to the left or right of fixation for 140 ms, and was replaced by (iv) a blank screen that remained for 1650 ms, during which the subject was required to respond. Responses were timed from the offset of the picture. Trials were automatically paced and followed each other successively within a block.

Participants were told that they would see an object name, followed by a degraded image of an object, and

Fig. 1. Sample stimuli used in Experiment 1 and in the blurred condition of Experiment 2.

that their task was to decide whether the name and image matched by pressing either a button labelled "yes" or a button labelled "no." Half of the participants used their right index finger to press "yes" and their left to press "no." For the other half, the position of the buttons was switched. Participants were instructed not to move their gaze from central fixation during the whole experiment.

2.2. Results

Error rates and response times (RTs) were subjected to separate repeated measures ANOVAs with object domain (living vs. nonliving) and visual field/hemisphere (LVF/RH vs. RVF/LH) as independent variables. Four stimulus items were removed from the analyses (two from each domain), because their average error rates exceeded 50%. Means and standard deviations for error and response time data are provided in Table 1.

2.2.1. Error data
Error data showed a reliable effect of object domain. Participants made more errors identifying nonliving things ($M = 14.0\%$, $SE = 0.6$) than they did identifying living things ($M = 9.8\%$, $SE = 0.5$), $F(1,47) = 52.0$, $p < .001$. The estimated effect size of this main effect was .53 (given as partial η^2). Neither the main effect of visual field, $F(1,48) = 1.8$, $p = .18$, nor the domain by visual field interaction, $F(1,47) = 0.0$, $p = .99$, was significant.

2.2.2. RTs
RTs to erroneous responses were removed before analysis. Likewise, responses deviating from an individual subject's mean within a condition by more than three standard deviations were also removed. This latter procedure affected less than 1% of data points in all conditions.

There was a reliable effect of object domain. Participants were slower to identify nonliving things ($M = 654$, $SE = 19.4$) than they were to identify living things ($M = 608$, $SE = 18.7$), $F(1,47) = 57.7$, $p < .001$. The estimated effect size of this main effect was .55 (given as partial η^2). The main effect of visual field was marginally significant, with participants being slower to identify objects presented in the right visual field ($M = 636$, $SE = 19.4$) than the left visual field ($M = 626$, $SE = 18.6$),

$F(1,47) = 3.3$, $p = .08$. Importantly, the object domain by visual field interaction, $F(1,47) = 5.4$, $p < .01$ was significant. Simple effects analysis revealed the interaction to be due to the fact that nonliving things are identified more slowly in the RVF/LH ($M = 663$, $SE = 19.5$) than in the LVF/RH ($M = 645$, $SE = 19.8$), $F(1,47) = 8.3$, $p < .01$, while living things are unaffected by hemifield of presentation. These results are illustrated in Fig. 2 (the bars represent 95% confidence intervals that were computed according to Loftus & Masson's, 1994; formula for within-subject designs).

2.3. Discussion

This experiment investigated the effects of hemifield of presentation on identification of blurred objects belonging to the domains of living and nonliving things. As expected, the results reveal that living things were identified faster and more accurately regardless of hemifield of presentation. However, there was also an interaction between hemifield and object domain, such that the response times for identification of nonliving objects in the RVF/LH were slower than in the LVF/RH. Thus, in line with our prediction, nonliving identification performance in the RVF/LH was less effective than any other condition. Contrary to our expectation however, there was no effect of hemifield on the identification of living things.

The overall effect of object domain, in the form of a living things advantage in identification, was strong. This large effect indicates that sub optimal viewing conditions hurt identification of nonliving objects more than identification of living objects, and it is consistent with the hypothesis that the informativeness of objects' global shape is generally higher for living than for nonliving things. In this experiment, the viewing conditions were sub optimal in a number of ways: The images were blurred, presentation time was relatively short, and the images were presented peripherally. There was, however, no

Table 1
Condition means for errors and response times in Experiment 1

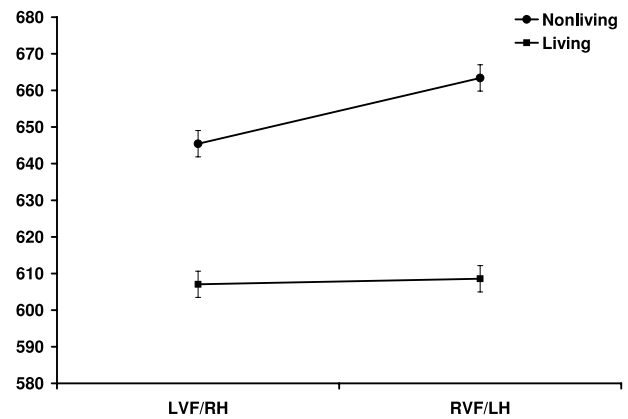| Condition	% Errors	Response times in ms
Living/RVF	10.3 (4.2)	609 (136)
Living/LVF	9.4 (4.3)	607 (127)
Nonliving/RVF	14.4 (5.7)	663 (137)
Nonliving/LVF	13.6 (5.2)	645 (135)

Standard deviations in parentheses.

Fig. 2. Interaction plot for response time (ms) cell means in Experiment 1. Error bars represent within-subject confidence intervals (cf. Loftus & Masson, 1994).

optimal presentation baseline to compare with in this experiment. Therefore, the overall category difference, although telling, cannot serve as the basis for any firm conclusions.

The effect of hemifield on the identification of nonliving things is also compatible with the hypothesis that the informativeness of objects' global shape is generally lower for nonliving things. On this view, the combination of a lack of useful global information, as well as a LH processing bias toward higher visual frequencies, which were unavailable in the stimulus images, will result in less efficient identification. However, this should also have led to more efficient identification in the living things-LVF/RH condition than in any other condition; but this was not the case, as hemifield of presentation had no discernable effect on the identification of living things.

This interaction could probably be explained in a number of ways. For instance, it is possible that the lack of visual detail and high spatial frequencies poses no serious problems for either hemisphere as long as the available global shape information is relatively useful. The global precedence effect (i.e., the fact that global patterns interfere with the processing of local patterns but not vice versa, e.g., Navon, 1977) may indicate that global information is a "first choice" in most processing tasks, and that the processing of local visual detail is relied on only when global information proves insufficient or less useful. Thus, a hemispheric difference in processing global and local information may show itself in object identification only when a lack of visual detail implies a lack of information regarding an object's identity, which, if the hypothesis concerning the informativeness of objects global shape is correct, would be the case for nonliving objects in this experiment.

However, there are other interpretations that at present are compatible with the overall pattern of data. In the word–picture matching task the label was presented first, and remained on screen for a relatively long time (1700 ms). This may have allowed participants to assemble an imagery representation of the named object. Visual imagery has been shown, under certain conditions, to depend more on RH-processes than on LH-processes (Sergent, 1989) and thus may have caused the effect of hemifield on the identification of nonliving objects. In particular, it has been suggested that because visual images may be of relatively low resolution, any LVF/RH advantages in visual imagery may be a result of the RH bias toward low spatial frequencies (Sergent, 1989; see Hellige, 1993 for a discussion). Thus, the RH advantage for processing nonliving things may simply be due to the RH being more adept at generating low-resolution imagery. The fact that there was no hemifield effect for living things could then be attributed to a ceiling effect, perhaps caused by the relative ease of generating images for living objects in general.

Another concern is the possibility that the large overall advantage for living things observed in this experi-

ment reflect the use of language-based stimuli. A majority of the category specific deficits observed in patients with brain damage has been attributed to problems with conceptual semantic object memory (Capitani, Laiacona, Mahon, & Caramazza, 2003). In addition, there is evidence from semantic feature norms indicating that the conceptual representations of living things cluster more tightly than those of nonliving things (Garrard, Lambon-Ralph, Hodges, & Patterson, 2001). Thus, it is conceivable that the large category-effect reflects more efficient semantic processing of living concepts rather than visual processing of global shape.

Finally, to attribute the pattern of results in this experiment to the blurring of the object images, and thus to differences in the informativeness of living and nonliving objects' global shapes, a comparison condition with clear images would be required.

3. Experiment 2

Experiment 2 was designed primarily to provide a comparison condition using clear object images, but also to replicate the pattern of results in Experiment 1. This will provide a firmer basis for evaluating the hypothesis concerning the informativeness of objects' global shapes, and for an interpretation of the interaction observed in Experiment 1 between object domain and hemifield of presentation. Specifically, we wanted first to confirm that the large category-effect observed in Experiment 1 was indeed partly a consequence of the blurring of the object images, and second, to rule out language-based, imagery-based, or other alternative explanations of the hemifield effect on identification of nonliving objects in Experiment 1.

Thus, in Experiment 2, we added a condition in which the images appeared without blurring, clear, and with full visual detail. We would expect to observe a smaller category-effect in this condition compared to the blurred condition. Also, if the effect of hemifield on the identification of nonliving things in Experiment 1 was a visual effect related to the lack of information in the global shape of nonliving objects, we should see it attenuated in the clear condition. Furthermore, to reduce participants' opportunities for imagery generation, we used a *picture–name* verification task in Experiment 2, rather than the *name–picture* verification task used in Experiment 1. Replicating the pattern of results obtained in Experiment 1 using such a task would allow a more confident attribution of the results to visual processing of the pictures, as opposed to imagery generation.

3.1. Method

3.1.1. Participants

The participants were 32 unpaid volunteers (18 women and 14 men with a mean age of 23.8 years)

recruited on the campus of the University of Tromsø. All were students at the university, and all of them were unaware of the specific purpose of the experiment. All participants were right-handed by self-report, native speakers of Norwegian, and had normal or corrected to normal vision. None had participated in Experiment 1.

3.1.2. Design, apparatus, and stimuli

For this experiment, we used a 2 (blurred versus clear images) by 2 (RVF/LH versus LVF/RH) by 2 (living versus nonliving objects) within-group design. The experiment was controlled by an IBM portable computer with 14 in. (35.6 cm) screen. Stimuli were presented and responses recorded using SuperLab software.

Stimuli consisted of 96 pictures of the same 48 objects used in Experiment 1. Half the pictures were blurred, and were identical to the ones used in Experiment 1. The other half consisted of clear (i.e., not blurred) versions of the same pictures.

3.1.3. Procedure

The pictures were arranged in eight blocks of 56 trials, of which the first eight trials in each block were practice trials showing objects not included in the experiment. Four of the blocks contained blurred images, the other four clear images. Assignment of trial types to blocks was otherwise identical to that of Experiment 1. The order of presentation of the blocks was derived from a Latin square matrix, and every other block was blurred or clear.

A trial proceeded as follows: (i) A fixation cross in the centre of the screen, which remained for 500 ms. It was replaced by (ii) an object image (blurred or clear) to the left or right of central fixation, presented for 140 ms. (iii) An object label (matching or mismatching the preceding picture) was then presented in the centre of the screen for 3000 ms or until the participant responded. Responses were timed from the onset of the label. Trials were automatically paced and followed each other successively within a block.

Participants were told that they would see an object image that in parts of the experiment would be clear and in other parts blurred, followed by a name of an object, and that their task was to decide whether the image and name were a match. Instructions were otherwise as in Experiment 1.

3.2. Results

Error rates and response times were subjected to separate repeated measures ANOVAs with blurring (blurred or clear), object domain (living vs. nonliving) and visual field/hemisphere (LVF/RH vs. RVF/LH) as independent variables. Means and standard deviations for error and response time data are provided in Table 2.

Table 2
Condition means for errors and response times in Experiment 2

Condition	% Errors	Response times in ms
Blurred pictures		
Living/RVF	9.3 (6.1)	751 (168)
Living/LVF	10.0 (5.7)	745 (150)
Nonliving/RVF	15.1 (6.0)	812 (167)
Nonliving/LVF	13.5 (6.9)	787 (152)
Clear pictures		
Living/RVF	6.6 (5.8)	723 (144)
Living/LVF	7.0 (4.9)	715 (133)
Nonliving/RVF	9.3 (4.6)	733 (166)
Nonliving/LVF	8.6 (4.3)	736 (154)

Standard deviations in parentheses.

3.2.1. Error data

Error data showed a reliable main effect of blurring. Participants made more errors identifying blurred object images ($M = 12.0\%$, $SE = 0.9$) than clear object images ($M = 7.9\%$, $SE = 0.7$), $F(1,31) = 35.7$, $p < .001$. The main effect of object domain was also significant, with more errors to nonliving objects ($M = 11.6\%$, $SE = 0.7$) than to living objects ($M = 8.3\%$, $SE = 0.9$), $F(1,31) = 23.0$, $p < .001$. Crucially, these main effects were qualified by an interaction between blurring and object domain, $F(1,31) = 13.7$, $p < .01$, with a larger domain difference to blurred stimuli (nonliving $M = 14.3\%$, $SE = 1.0$; living $M = 9.7\%$, $SE = 1.0$) than to clear stimuli (nonliving $M = 9.0\%$, $SE = 0.7$; living $M = 6.9\%$, $SE = 0.9$). No other main effects or interactions were significant.

3.2.2. RTs

Response times to erroneous responses were removed before analysis. Likewise, responses deviating from an individual subject's mean within a condition by more than three standard deviations were also removed. This latter procedure affected less than 2% of data points in all conditions.

Response time data are illustrated in Fig. 3 [the bars represent 95% confidence intervals that were computed according to Loftus and Masson's (1994) formula for within-subject designs]. The analysis revealed a reliable effect of blurring. Participants were slower to identify blurred object images ($M = 774$, $SE = 27.8$) than they were to identify clear object images ($M = 726$, $SE = 26.0$), $F(1,31) = 13.8$, $p < .01$. The main effect of object domain was also significant, with participants being slower to identify nonliving objects ($M = 767$, $SE = 27.1$) than living objects ($M = 733$, $SE = 25.3$), $F(1,31) = 47.1$, $p < .001$. Importantly, these main effects were qualified by an interaction between blurring and object domain $F(1,31) = 21.1$, $p < .001$, with a larger domain difference to blurred stimuli (nonliving $M = 800$, $SE = 27.8$; living $M = 748$, $SE = 27.9$) than to clear stimuli (nonliving $M = 734$, $SE = 28.1$; living $M = 719$, $SE = 24.3$).
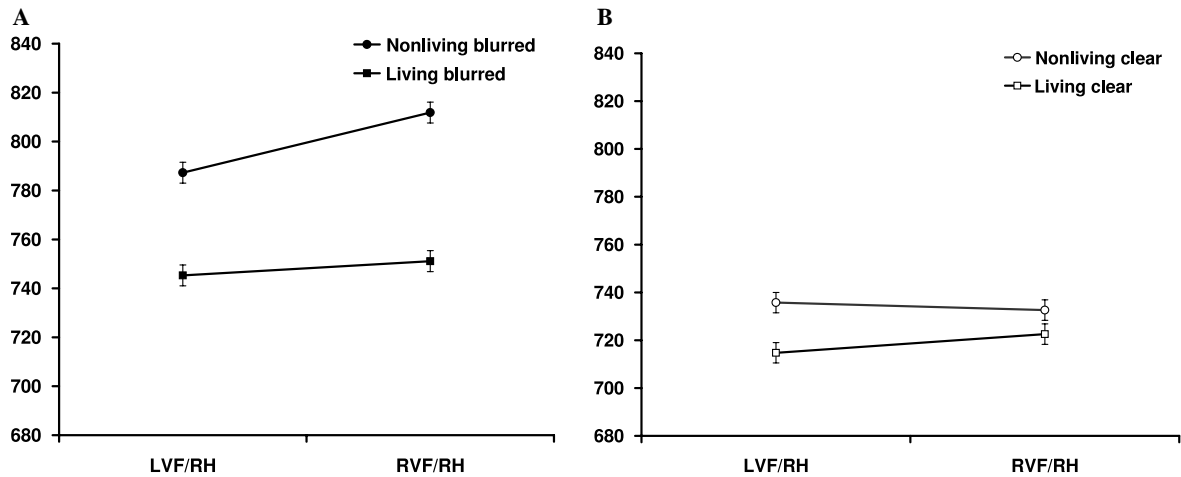
Fig. 3. Interaction plot for response time (ms) cell means in Experiment 2. (A) Blurred stimuli. (B) Clear stimuli. Error bars represent within-subject confidence intervals (cf. Loftus & Masson, 1994).

The analysis also revealed a three-way interaction between blurring, object domain and visual field, $F(1,31) = 6.2$, $p < .05$. A separate ANOVA on the data from the clear picture trials revealed a main effect of object domain, with participants being slower to identify nonliving objects ($M = 734$, $SE = 28.1$) than living objects ($M = 719$, $SE = 24.3$), $F(1,31) = 4.8$, $p < .05$. The estimated size of this effect was .13 (given as partial η^2). Neither the main effect of visual field, nor the interaction was significant. In contrast, a separate ANOVA on data from the blurred picture trials revealed both a main effect of object domain, with participants being slower to identify nonliving objects ($M = 800$, $SE = 27.8$) than living objects ($M = 748$, $SE = 27.9$), $F(1,31) = 94.7$, $p < .001$. (partial $\eta^2 = .75$) and, crucially, an interaction between object domain and visual field, $F(1,31) = 4.1$, $p < .05$. The main effect of visual field was not significant. Simple effects analysis revealed the interaction to be due to the fact that nonliving things are identified more slowly in the RVF/LH ($M = 812$, $SE = 29.5$) than in the LVF/RH ($M = 787$, $SE = 26.9$), $F(1,31) = 6.9$, $p < .05$, while identification of living things is relatively unaffected by hemifield of presentation, $F < 1$.

3.3. Discussion

This experiment investigated the effect of a lack of high frequency visual information on the identification of living and nonliving objects in the right and left visual hemifields using a picture–name verification paradigm. In line with our previous considerations, the overall living things identification advantage was markedly increased when object images were blurred (and local visual detail attenuated) as opposed to clear (with visual detail available). Importantly, the pattern of results for the blurred conditions of this experiment replicates those of Experiment 1, with slower identification of nonliving

things in the RVF/LH compared to the LVF/RH. In contrast, this effect of hemifield of presentation on nonliving objects was not present when pictures were presented in their clear versions.

These results indicate that the effects observed in Experiment 1, and in the blurred conditions of this experiment, are attributable to visual processing. The marked increase in the living things advantage with the blurred pictures compared to the clear, significantly weaken the plausibility of an explanation in terms of the structure of semantic representations for the large advantage in Experiment 1. Furthermore, the fact that identification of nonliving things was slower in the RVF/LH compared to the LVF/RH when pictures were blurred but not when they were clear, supports the interpretation that this hemifield effect was the result of a lack of local visual detail or high spatial frequency in the stimulus images. Finally, the experiment eliminates an alternative explanation in terms of lateralisation of imagery generation processes.

4. General discussion

In two experiments, we examined the effects of object domain (living or nonliving), availability of high frequency visual information, and hemifield of presentation on the identification of common objects. The main findings were that: (i) When local visual detail or high frequency information is unavailable in the visual representation of the objects, identification of living things is considerably more efficient than identification of nonliving objects. (ii) This living things advantage is not nearly as marked when stimuli provide high frequency, as well as low frequency, information. (iii) A lack of high frequency visual information induces a LH disadvantage for the identification of nonliving objects.

The purpose of these experiments was to illuminate the possible causes of the category specific living things advantage observed previously in well-controlled object identification experiments using neurologically intact participants (Gerlach, 2001; Laws, 2000; Laws & Neve, 1999; Låg, 2005). Specifically, we wanted to test the hypothesis that the living things advantage over nonliving things is partly due to statistical differences in the informativeness of objects' overall global shape. This hypothesis states that the global shapes of living things generally reveal more of their identity than the global shapes of nonliving things and that, therefore, to the extent that object identification relies on analysis of global shape, living things will be advantaged.

The present results were consistent with the above hypothesis. When stimulus conditions (blurred pictures) forced participants to rely more on global shape, the living things advantage was exaggerated. Also, the global shape hypothesis predicted the LH disadvantage for nonliving things observed in Experiment 1 and in the blurred conditions of Experiment 2. Because of a bias toward high frequency visual information, the LH is less adept at processing stimuli that lacks visual detail. This disadvantage becomes especially pronounced when the available global information gives few clues to an object's identity.

Although, the LH disadvantage for nonliving objects is rather small and present only in the response time data, it is reliable enough to appear in experiments using slightly different stimulus presentation paradigms and different participants. Furthermore, hemisphere biases in visual processing of blurred stimuli in neurologically intact individuals are generally quite small, and frequently show themselves only in the more sensitive response time measures (e.g., Michimata & Hellige, 1987; Sergent, 1989).

The present results also accord with previous findings that indicated a role for global or outline shape in the living things identification advantage. A larger living things advantage with object silhouettes than with ordinary line-drawings in an object decision task led Lloyd-Jones and Luckhurst (2002) to conclude that outline shape is a particularly important mediator of object recognition for living things, and that there may be less useful information in the object contours of nonliving things. Identification of living things also seems to occur at lower levels of spatial resolution than identification of nonliving things (Vanucci et al., 2001), thus again indicating a relative lack of useful information in the global shapes of nonliving things.

The convergence of the findings from the present experiments with the two previous studies of Lloyd-Jones and Luckhurst (2002) and Vanucci and colleagues (Vanucci et al., 2001) is encouraging. Particularly, since a matter of growing concern in the investigation of processes underlying object identification is the question of whether the particular stimulus set being used can be described by properties that are not common to objects or object classes in general. Such properties may invalidate any conclusions drawn from results obtained. Interestingly, the stimulus sets used in the present experiment (realistic drawings taken from visual dictionaries) and in the studies of Lloyd-Jones and Luckhurst (2002; line drawings from the Snodgrass & Vanderwart, 1980 set) and Vanucci and colleagues (Vanucci et al., 2001; photographs) are all different. Thus, it is less likely that the present results, or those of the other two studies, can be validly attributed to idiosyncrasies of a particular stimulus set rather than to properties of the visual representations of objects in general. The tasks used in these studies also differ considerably, making analogous concerns about task-specific influences less pressing.

We conclude that the informativeness of objects' global shapes plays a causal role in the living things advantage in object identification. This implies that differences in global shape informativeness should be taken into account when interpreting differences in object identification performance across object domains or categories.

Acknowledgments

Appendix A

List of picture names for the objects used as stimuli in Experiment 1 and 2

Living things		Nonliving things	
Pineapple	Dromedary	Hacksaw	Caravan
Orange	Crocodile	File	Aeroplane
Banana	Rhinoceros	Hammer	Helicopter
Raspberry	Tiger	Saw	Motorbike
Grapes	Horse	Wrench	Space shuttle
Apple	Squirrel	Vice	Sailing ship
Strawberry	Hare	Chainsaw	Trailer truck
Pear	Fox	Ladder	Pickup
Cucumber		Knife	
Broccoli		Fork	
Corncob		Whisk	
Pepper		Carafe	
Leek		Pitcher	
Radish		Grater	
Lettuce		Sieve	
Tomato		Frying pan	

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