Perception, 2004, volume 33, pages 531 – 546

DOI:10.1068/p5213

Ambiguous figures: living versus nonliving objects

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Received 10 March 2003, in revised form 15 December 2003; published online 16 April 2004

Abstract. Eleven series of figures were studied, each series ranging from one extreme interpretation via five ambiguous intermediates to a second extreme interpretation. Triplets consisting of an ambiguous exemplar in the middle flanked on the left and right by its two extreme interpretations were presented to large groups of subjects. The initial aim was to establish the levels of perceptual ambiguity of each exemplar in a series, and normative data on the ambiguous figures are provided for future reference and use. However, several biases were encountered and these were examined in more detail.

In experiment 1 the subject's task was to compare the middle figure with the flankers and draw an arrow from the middle figure towards the flanking extreme they judged the most similar. Here, an overall preference for the left extreme was found. Therefore the instructions were reversed in experiment 2; flankers had to be compared with the middle figure. The preference for the left extreme remained for figures of living objects, but for nonliving objects the preference switched to the right extreme. To do away with any effect of the arrows, in experiment 3 subjects were divided into two groups each receiving different instructions and were asked to circle one of the extremes. However, the pattern of biases remained the same. The bias found with figures of living objects may be explained on the basis of top – down processes. For nonliving figures, an hypothesis based on bottom – up processes like neural fatigue was considered but rejected.

1 Introduction

Fisher (1967a, 1967b) was among the first to determine the level of ambiguity of ambiguous figures—figures that give rise to at least two different perceptual interpretations (eg Attneave 1971). Fisher's aim was to get a 'pure' ambiguous figure: a figure that elicits as many responses to one interpretation (eg duck) as to the other (eg rabbit). To arrive at such a pure ambiguous figure he created a series of ambiguous figures differing in ambiguity, and presented each one separately to the subjects and scored which of the two possible interpretations they indicated.

In the studies presented here, our initial aim diverged from Fisher's in that we were particularly interested in the series as such: in establishing the stepwise increase or decrease in similarity from one exemplar in a series to the next. For that reason, we could not follow Fisher's procedure, since presenting one ambiguous figure at a time reveals at most the similarity of this figure to say an exemplary or archetypical duck figuring in the subject's mind, but not to a particular unambiguous endpoint of a series.

We needed this similarity information for the manufacturing of what we called a 'visual-flexibility measure'. This measure formed part of a study on the benefit of visual diagrams in analogical problem solving and the influence of expertise in the problem-solving domain (Verstijnen and Wagemans, in preparation). In these studies we wondered whether an individual's flexibility might influence the speed of bridging between target and source in analogical problem solving. To quantify each subject's visual flexibility in this study, a number of series of figures was needed, gradually changing from one

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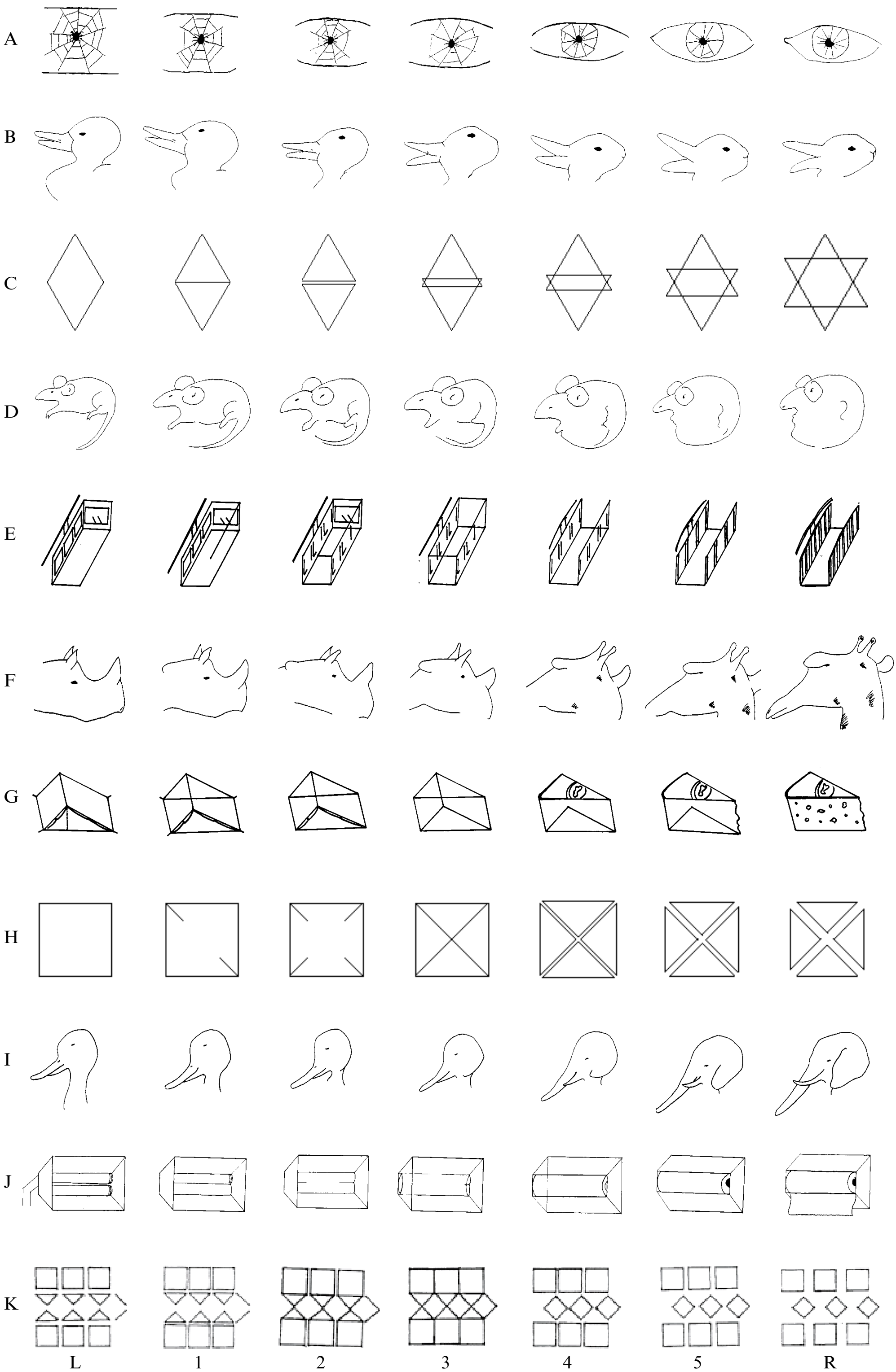

Figure 1. All series of figures as used in the experiments.

interpretation to another. The subject's flexibility was quantified by the moment of switch in interpretation. To assure a particular interpretation to start with, the series needed to begin with an unambiguous figure and range from this extreme interpretation via intermediate ambiguous figures to the other extreme interpretation.

We found the required series of figures in the doctoral thesis by Hogeboom (1995). The extremes (L and R, in figure 1) are meant to be unambiguous, but we still needed to verify the levels of ambiguity for all the intermediate figures. There was absolutely no guarantee that these series were well calibrated in the sense that the levels of ambiguity were in a perfectly consistent rank order, nor that the middle level was indeed perfectly inbetween interpretation L and R, nor that the step size between consecutive levels of ambiguity was similar across the whole range, nor that the respective levels of ambiguity were indeed comparable for the different ambiguous figures.

Hogeboom's collection(1) consists of twelve series of 7 figures (see figure 1). Some of these series have a classical example of an ambiguous figure as their middle figure, such as Jastrow's (1900) famous duck–rabbit figure (figure 1, B3), and the man–rat figure (Bugelski and Alampay 1961; figure 1, D3); other series consist of newly created figures.

The experiments presented in this article differ from those in earlier research regarding the procedure of determining the ambiguity level for each figure in a series. To get these ambiguity levels, we decided to flank an ambiguous figure with its two extremes L and R in figure 1, and present these triplets to a large number of subjects. The subjects' task was to relate the middle figure to the two extremes (or vice versa).

However, we might introduce a presentation-order effect by presenting triplets in the left to right order only. A previously perceived pattern (perceptual history) can persist in the processing of a subsequent pattern (ie hysteresis; eg Kelso 1995), and presenting from left to right only might cause one of the extremes to exert more influence on the middle figure. As a matter of good methodological conduct, we therefore decided to have enough subjects to inverse the presentation order and present the figures right to left as well. Although we did not expect this to make a difference how the middle figure was judged, since the perceptual history is rather short, it turned out that swapping the two extremes was a relevant manipulation. Subjects showed a clear preference for the rightmost extreme of a triplet independently of the order of presentation (experiment 1). This preference, however, was mostly found with figures of living objects as contrasted with figures of nonliving objects. The data for the figures of nonliving objects turned out to be biased by a preference for right-pointing arrows with which subjects could indicate their preference (experiment 2). A final experiment showed that this latter bias might in fact be due to the combined effect of right-pointing arrows together with a preferred direction of comparison from left to right (experiment 3).

2 Experiment 1

2.1 *Method*

2.1.1 *Subjects.* A total of 401 subjects took part in the experiment, 85 male and 316 female. All were first-year psychology students at the University of Leuven. They received course credit for their participation. Mean age was 18.56 years.

2.1.2 *Stimuli.* Figure 1 shows the series as published(2) by Hogeboom (1995). For each of these series, triplets were created with the two extreme figures flanking one of the intervening figures. In figure 2a, for example, the third intervening figure of series F

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(2) Because of technical difficulties, one of the twelve series by Hogeboom was not included in our experiments.

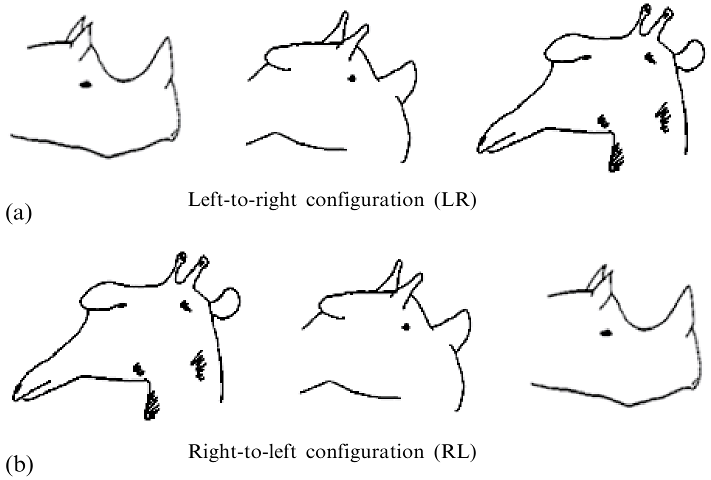


Figure 2. Example of an LR configuration and an RL configuration.

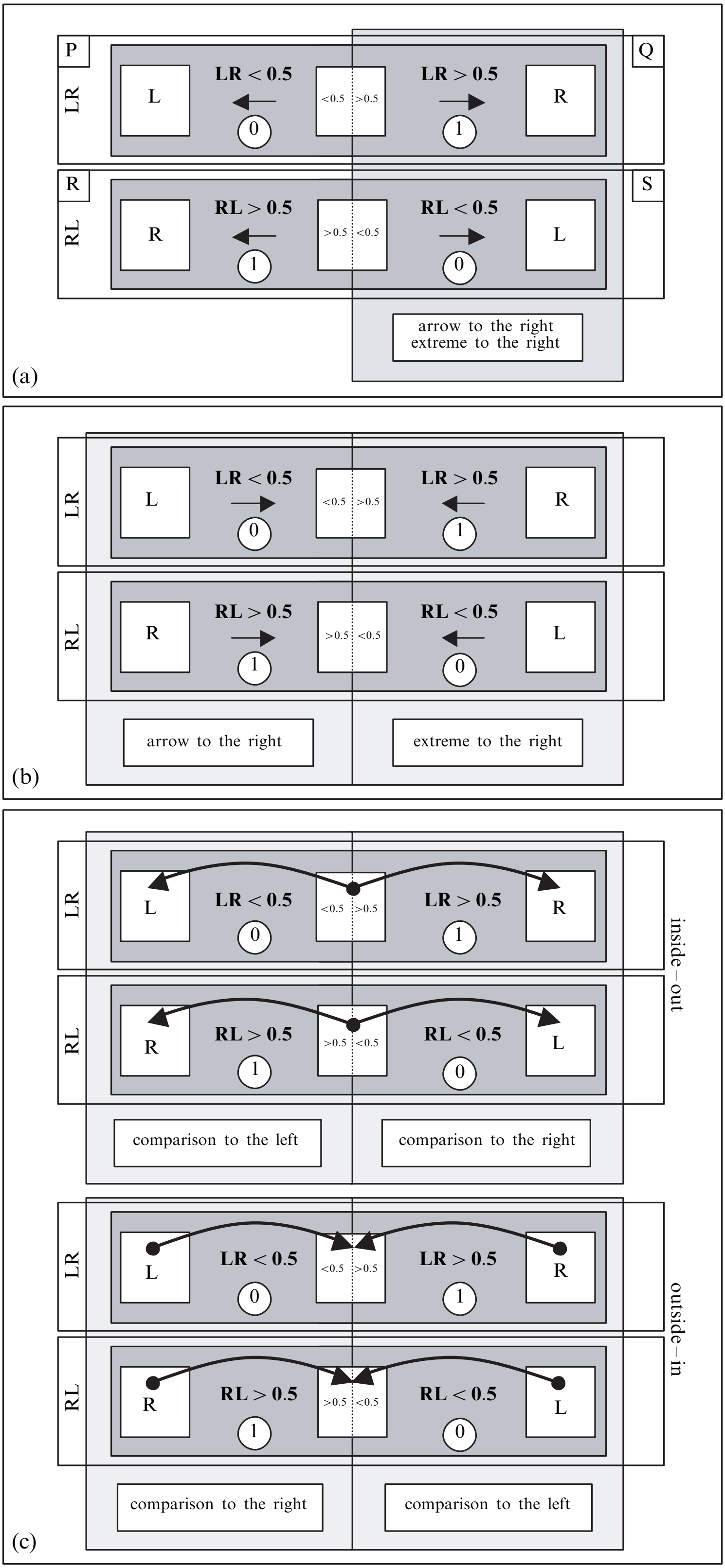
(ie figure 1, F3), is flanked by its left extreme (L) on the left and by its right extreme (R) on the right. By placing the left extreme on the left and the right on the right the order of the images as presented in figure 1 is preserved, and therefore configurations like this were called LR configurations. In contrast, RL configurations were created by placing the left extreme of a series on the right of the intervening figure and the right extreme on the left. An example of an RL configuration is shown in figure 2b. As for each of the five intervening figures such a triplet could be created, this resulted in five LR configurations and five RL configurations for each series. A total of 55 triplets (5×11 series) resulted per configuration.

Two kinds of stimulus booklets were created: one with LR configurations only, and one with RL configurations only. Each booklet consisted of 5 upright A4 pages with 11 triplets placed underneath each other on each page. The order of triplets was randomised with the restriction that one instance only of a series occurred on each page. This way 22 random orders were created for the whole set of figures. These 22 random orders were applied to both LR configurations and RL configurations; hence 44 different booklets were constructed. These 44 booklets were then multiplied to have enough booklets, one for each subject.

A one-page instruction sheet was attached as the front page to each booklet. On this page subjects had to fill in their gender, age, and hand dominance.

2.1.3 *Procedure.* All subjects were assembled in one large lecture room. Each subject was given one booklet and was told to read carefully through the instructions on the first page. The instructions informed the subjects how to place an arrow in one of the two empty spaces between the middle figure and the extremes. They had to place an arrow pointing to the right in the empty space on the right of the middle figure if they thought that the middle figure resembled most the figure to the right, and vice versa for the left figure. Subjects were instructed to work through the booklet in a serial manner, and not to look back on previous pages. It generally took subjects 3 to 5 min to work their way through instructions and stimuli.

Figure 3 (opposite). Schematic overview of the experiments: (a) experiment 1, (b) experiment 2, and (c) experiment 3. An ambiguous figure was placed between its two extreme interpretations L and R (see figure 2). L was placed on the left and R on the right in configuration LR and the other way round in configuration RL. Circled numbers denote the points that were assigned to an ambiguous figure whenever a subject placed an arrow in this area. Maximal ambiguity is 0.5.


P
Q
LR
L
LR < 0.5
<0.5
>0.5
LR > 0.5
R
0
1
R
S
RL
R
RL > 0.5
>0.5
<0.5
RL < 0.5
L
1
0
arrow to the right
extreme to the right
(a)
LR
L
LR < 0.5
LR > 0.5
R
RL
RL > 0.5
RL < 0.5
arrow to the right
extreme to the right
(b)
inside–out
comparison to the left
comparison to the right
outside–in
comparison to the right
comparison to the left
(c)

2.1.4 *Scoring.* If subjects indicated that the middle figure in an LR configuration triplet bore a closer resemblance to the left figure, then this trial was scored as 0. An arrow to the right figure in an LR configuration was scored as 1 (see figure 3a). Since the figure to the right in an LR configuration is the same as the figure to the left in an RL configuration, a subject's preference for the left figure was scored as 1 in RL configurations and a right figure preference was scored as 0. With this way of scoring, a fully ambiguous figure would get a mean score of 0.5 when averaged over all subjects. Furthermore, irrespective of type of configuration (LR or RL), this way of scoring permits us to conclude that, when a figure gets a score lower than 0.5, it can be read as being a figure with a tendency towards the leftmost figure of a series as presented in figure 1 (ie towards the L extreme). In the same vein, figures with a mean score higher than 0.5 resemble the rightmost extreme of the series more (ie the R extreme).

2.2 *Results*

2.2.1 *General.* A total of 200 subjects got a booklet with LR configurations, 201 subjects got the RL configurations. Male and female subjects were pooled because no gender differences could be established.

2.2.2 *LR – RL manipulation.* Because the differences for a stimulus under LR configuration and RL configuration were rather small in comparison to the differences that occurred between different stimuli, we decided to treat the LR and RL data as repeated measures. Hence, each of the 55 figures was treated as a subject in a repeated-measures design, with LR configuration and RL configuration as a repetition factor called Configuration.

An ANOVA revealed a significant effect of Configuration ($F_{1,54} = 22.948$, $p < 0.001$); in other words, the responses on the LR configurations differed clearly from those on the RL configurations. The mean difference between LR configuration and RL configuration was 0.035 (SD = 0.054) ranging from −0.048 difference to 0.213. The positive sign of this mean difference indicates a preference for the extreme placed to the right of the middle figure. To see why a positive sign indicates a preferred right placement it is helpful to inspect figure 3a. Figure 3a gives an abstract account of the types of configurations, the arrow directions, and the scoring. Moreover, it shows the four possible conditions (P, Q, R, S) in which a stimulus can occur depending on its ambiguity level (< 0.5 or > 0.5) and the type of configuration (LR or RL). Figure 3 shows that in order to compare the LR configuration with the RL configuration, condition Q in figure 3 is to be compared with condition R, and condition P is to be compared with S. If the mean for a certain stimulus obtained in condition Q is larger than the mean for the same stimulus in condition R ($Q - R > 0$), this implies that subjects must have assigned more 1s (since an arrow placed here was scored as a 1) to condition Q than to condition R. A similar reasoning applies to a comparison between conditions P and S. Hence, if the LR configuration (that is conditions P and Q) scores higher than the RL configuration (R and S), it means that conditions Q and S are preferred. Closer inspection of figure 3 shows what Q and S have in common. Preferring Q and S indicates that subjects have a tendency to prefer the rightmost figure of a triplet, independently of whether it concerns an LR or RL triplet. Further inspection of the data revealed that this preference for rightmost figures seemed to depend on the level of ambiguity of the middle figure. To that end, we determined for each stimulus its mean score over LR configurations and RL configurations, and used this mean to calculate the absolute distance of this mean to the nearest extreme. For example, for figure 1, A2 the mean is 0.283. Hence the distance to the closest extreme is $|0 - 0.283| = 0.283$. The resulting distances were labeled Ambiguity levels, and could ultimately range between 0 (no ambiguity; all subjects preferred one of the two extremes) and 0.5 (perfect ambiguity; half of the subjects preferred extreme L and the other half extreme R). Ambiguity levels turned out to range between 0.067 and 0.491. Ambiguity level was added to the ANOVA as a covariate and was shown to contribute significantly (Wilks's $\Lambda = 0.805$, $p = 0.004$), indicating that the larger the ambiguity level the larger the difference between LR configuration and RL configuration. In other words, the more ambiguous the middle figure, the larger the preference for indicating the rightmost extreme.

2.3 *Discussion*

In experiment 1 we established for each of the intervening figures in a series of figures, ranging from an extreme interpretation to another extreme interpretation, how much it resembled the extremes.

We found that when a triplet of figures was presented with an intervening ambiguous figure placed between two extreme interpretations, the rightmost figure of a triplet exerted the strongest influence on the interpretation of the middle figure. This preference for rightmost figures in a triplet turned out to be related to the level of ambiguity of the middle figure: the more ambiguous this middle figure is the larger the preference.

A confounding factor in experiment 1, however, was that in order to indicate the rightmost figure subjects had to draw a right-pointing arrow. A right-pointing arrow coincides with the writing direction and is probably drawn more easily. It may therefore have been drawn more readily in our experiment. Certainly, whenever subjects are unsure, as will probably be the case with ambiguous figures, they may have turned to the easiest way out, ie drawing an arrow to the right. This may explain why the preference for rightmost figures was found more manifest with figures that are more ambiguous. An explanation based on the ease of drawing a particular kind of arrow may rule out more interesting explanations based on top – down or bottom – up influences on ambiguous figures. Moreover, it might have affected the ambiguity levels.

Hence, we felt that this alternative explanation in terms of right-pointing arrows had to be examined in a second experiment.

3 Experiment 2

3.1 *Method*

3.1.1 *Subjects.* A total of 432 subjects took part in the experiment, 92 male and 340 female. All were first-year psychology students at the University of Leuven. Mean age was 18.57 years. Their cooperation in this experiment was voluntary, and was kindly asked for at the end of a first-year class meeting. None of these subjects took part in experiment 1.

3.1.2 *Stimuli and procedure.* The stimulus booklets were identical to the ones used in experiment 1, except that a different front page was attached. This page instructed subjects to draw a right-pointing arrow from the leftmost figure to the middle figure whenever they found that this extreme resembled the middle figure most; and to draw a left-pointing arrow from the rightmost figure to the middle figure whenever they found that the rightmost figure resembled the middle figure most (see figure 3b). Note that inverting the direction of the arrows with respect to those in experiment 1 coincides with a change in instruction; whereas subjects in experiment 1 were asked to rate the middle figure with respect to the two extremes, in experiment 2 subjects had to rate the extremes with respect to the middle figure.

3.2 *Results*

3.2.1 *General.* 219 subjects got a booklet with LR configurations, 213 subjects got the RL configurations. Male and female subjects were pooled because no gender differences could be established.

3.2.2 *LR – RL manipulation.* With respect to the LR – RL manipulation, experiment 2 also indicated a preference for right extremes, reflected in a higher mean in the LR configuration as compared with the RL configuration following the line of reasoning of experiment 1. As we did in experiment 1, we will call this factor Configuration. Further extension of the line of reasoning of experiment 1 reveals that an effect of arrows pointing to the right should show up as an interaction between experiments and configurations. For right-pointing arrows in experiment 1 configuration LR should score higher than RL, while in experiment 2 this is reversed and RL should score higher than LR. We will call this factor Arrow direction. Hence, combining the data of experiments 1 and 2 allows us to reveal the separate contributions of Arrow direction and Configuration.

A 2×2 repeated-measures analysis on the data of experiments 1 and 2 with Experiment (1 and 2) and Configuration (LR and RL) as repetition factors and Ambiguity level as covariate, showed a main effect of Configuration ($F_{1,54} = 7.598$, $p = 0.008$) and a main effect of Arrow direction (Experiment $\times$ Configuration; $F_{1,54} = 20.451$, $p < 0.001$); no effect of Experiment could be established ($F_{1,54} = 2.593$, $p > 0.05$). A main effect of Configuration (LR > RL) indicates a preference for extremes to the right, while an effect of Arrow direction ($\rightarrow > \leftarrow$) indicates a preference for right-pointing arrows. Again the covariate Ambiguity level shows a significant contribution (Wilks's $\Lambda = 0.602$, $p < 0.001$).

Although a fruitful account of the combined data seems to be based on both a preference for extremes to the right and on right-pointing arrows, when applied to each series separately a different pattern emerges. To gain insight into the relative contributions of both factors to each series, we subtracted, for each series separately, the partial-effect size (η_p^2) of the factor Arrow direction (ie Configuration $\times$ Experiment) from that of the factor Configuration. For example, for series G the partial-effect sizes are 0.23 and 0.634 for Configuration and Arrow direction, respectively. Hence $\eta_p^2(\text{Configuration}) - \eta_p^2(\text{Arrow direction}) = 0.23 - 0.634 = -0.404$. Since this is a negative value, it indicates that for series G a larger effect for Arrow direction than for Configuration was found. In figure 4 the results are displayed according to the relative contributions of Configuration and Arrow direction. Figures with a dominance of Configuration are displayed on the left, while figures with Arrow direction dominance are displayed on the right (grey areas in figure 4). A remarkable arrangement occurs when displayed accordingly: on the left of figure 4 more figures of living objects (animals and faces) occur, whereas on the right more man-made nonliving figures occur. The only odd one out is series J.

Inspection of figure 4 inspired us to classify the figures into two categories; nonliving (series C, E, G, H, J, and K) and living (series A, B, D, F, and I), and redo the above repeated-measures analyses separately for each category. Figure 5 shows the results.

The 2×2 repeated-measures analysis on the nonliving figures only ($n = 30$) showed a significant effect of Arrow direction ($F_{1,29} = 17.901$, $p < 0.001$), and Experiment ($F_{1,29} = 7.752$, $p < 0.01$), but no main effect of Configuration ($F_{1,29} < 1$). In contrast, the 2×2 repeated-measures analysis on the figures of living objects only ($n = 25$) showed a significant effect only of Configuration ($F_{1,24} = 6.58$, $p < 0.05$), a trend for Arrow direction ($F_{1,24} = 4.153$, $p = 0.052$), and no effect for Experiment ($F_{1,24} < 1$). As in experiment 1, the covariate Ambiguity level contributed to the analyses; Wilks's Λ was 0.585 ($p = 0.006$) for the nonliving figures, and 0.197 ($p < 0.001$) for the figures of living objects.

These analyses reveal that figures of living objects are mostly influenced by right-placement and nonliving figures mostly by right-pointing arrows.

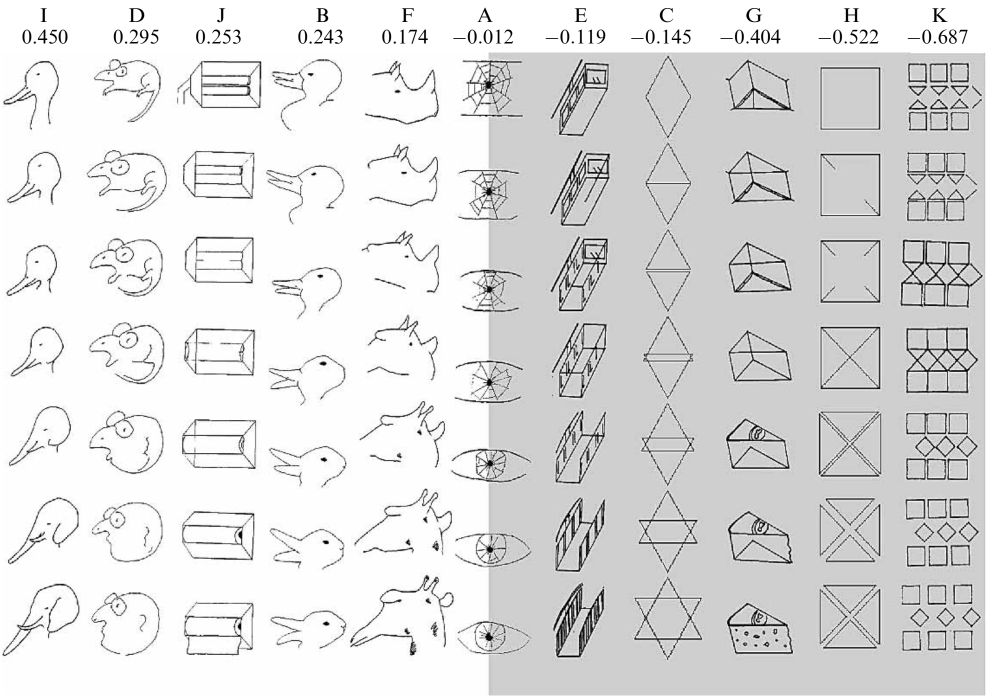


Figure 4. Ordering of the series as a result of the relative contribution of the factors Configuration and Arrow direction. It shows that more living series of figures occur on the left, ie on 'the Configuration side', while more nonliving figures occur on the right, ie on 'the Arrow direction side'. Above each series the result of the contribution calculation: η_p^2(Configuration) − η_p^2(Arrow direction) is displayed.

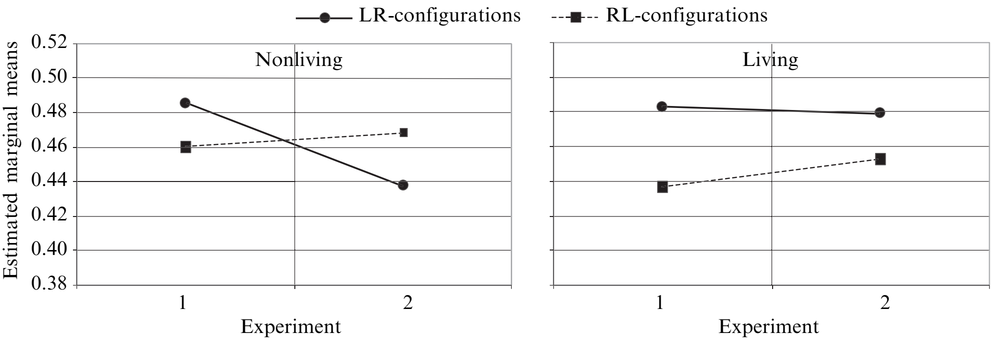


Figure 5. Combined results of experiments 1 and 2 for nonliving figures (on the left) and figures of living objects (on the right) separately. It shows that for nonliving figures only an interaction of configuration and experiment number could be established, indicating a preference for right-pointing arrows only, but no main effect of Configuration. For figures of living objects a strong main effect of Configuration can be noted, indicating a preference for rightmost figures in a stimulus triplet, although a small but significant interaction effect was also obtained.

The above analyses were based on the combined results of left-handed and right-handed subjects. Only a small number of left-handed subjects took part in the experiments: 25 in experiment 1 and 21 in experiment 2. Separate analyses on the data of only left-handed subjects did not reveal any significant effect, neither with the living and nonliving figures combined, nor when analysed separately.

Both to exclude the unwanted effect of right-pointing arrows on the results and to control for the influence of different instructions in experiments 1 and 2, we decided to run a third experiment. In this experiment, the subjects were asked to circle the extremes.

4 Experiment 3

4.1 *Method*

4.1.1 *Subjects.* A total of 317 subjects took part in the experiment. 73 male and 244 female. All were first-year psychology students at the University of Utrecht in the Netherlands; their mean age was 19.37 years. Their participation in this experiment was voluntary, and was kindly requested at the end of a first-year class meeting. The subjects did not participate in any of the previous experiments.

4.1.2 *Stimuli and procedure.* The stimulus booklets were identical to those in experiments 1 and 2, except that different front pages were attached. One front page instructed subjects to compare the middle figure to the extremes and to circle the leftmost extreme whenever they found that the middle figure resembled this extreme most; and to circle the rightmost figure whenever they found that the middle figure resembled this extreme most (ie the same instruction as in experiment 1). This we labeled the inside – out instruction. The other front page gave the reversed instructions; it instructed subjects to compare the extreme figures to the middle figure (ie the same instruction as in experiment 2). This condition we labeled outside – in instruction (see figure 3). As in experiment 1 and experiment 2, the LR and RL configurations were applied.

4.2 *Results*

4.2.1 *General.* 70 subjects got a booklet with LR configurations and inside – out instructions, and 96 subjects got the LR configurations with outside – in instructions. For the RL configurations booklets, these numbers were, respectively, 66 and 85 subjects. Male and female subjects were pooled because no gender differences could be established. The mean data for each series pooled over LR and RL configurations and inside – out and outside – in instructions are shown in table 1. Note that, although the series as presented in figure 1 were meant to progress gradually from one interpretation to the other, table 1 shows that most series have figures with scores close to the extreme values (0 or 1) and almost none have scores in the middle. These data suggest a sigmoid function instead of a straight line. We therefore decided to fit a sigmoid function to each series via binary logistic regression. This function is of the type: $y = [\exp(-a + bx)]/[1 + \exp(-a + bx)]$. The point of pure ambiguity ($y = 0.5$) and the constants a and b in the formula of the resulting regression lines for each series separately are listed in table 2, the regression lines themselves are displayed in figure 6. Note that, with the exception of series K, for the living series in general the

Table 1. Experiment 3. Means (with standard deviations in parentheses) for the series depicted in figure 1 as obtained when the results are pooled over LR and RL configurations.

Pooled LR and RL configurations	Series										
	A	B	C	D	E	F	G	H	I	J	K
1	0.054 (0.226)	0.047 (0.213)	0.019 (0.136)	0.035 (0.183)	0.044 (0.206)	0.025 (0.157)	0.073 (0.260)	0.060 (0.238)	0.063 (0.244)	0.050 (0.219)	0.054 (0.226)
2	0.416 (0.494)	0.202 (0.402)	0.032 (0.175)	0.091 (0.289)	0.114 (0.318)	0.035 (0.183)	0.069 (0.255)	0.274 (0.447)	0.085 (0.280)	0.079 (0.270)	0.066 (0.249)
3	0.691 (0.463)	0.710 (0.455)	0.162 (0.369)	0.101 (0.302)	0.352 (0.478)	0.073 (0.260)	0.142 (0.350)	0.565 (0.497)	0.164 (0.371)	0.328 (0.470)	0.842 (0.365)
4	0.927 (0.260)	0.943 (0.232)	0.338 (0.474)	0.808 (0.326)	0.839 (0.368)	0.662 (0.474)	0.817 (0.387)	0.718 (0.451)	0.880 (0.325)	0.782 (0.414)	0.883 (0.322)
5	0.965 (0.183)	0.975 (0.157)	0.811 (0.392)	0.940 (0.238)	0.912 (0.284)	0.950 (0.219)	0.871 (0.336)	0.899 (0.302)	0.965 (0.183)	0.953 (0.213)	0.940 (0.238)

Table 2. Experiment 3. Values of a and b in the equation $y = [\exp(-a+bx)][1+\exp(-a+bx)]$ for each series separately and the point of pure ambiguity ($y = 0.5$). Resulting curves are displayed in figure 6.

Parameters	Series										
	A	B	C	D	E	F	G	H	I	J	K
PPA[a]	2.420	2.617	4.223	3.459	3.249	3.764	3.552	2.765	3.348	3.317	2.710
a	3.711	5.039	6.309	6.973	5.076	8.251	5.438	3.150	6.373	5.562	4.982
b	1.533	1.925	1.494	2.016	1.562	2.192	1.531	1.139	1.904	1.677	1.839

[a] PPA = point of pure ambiguity.

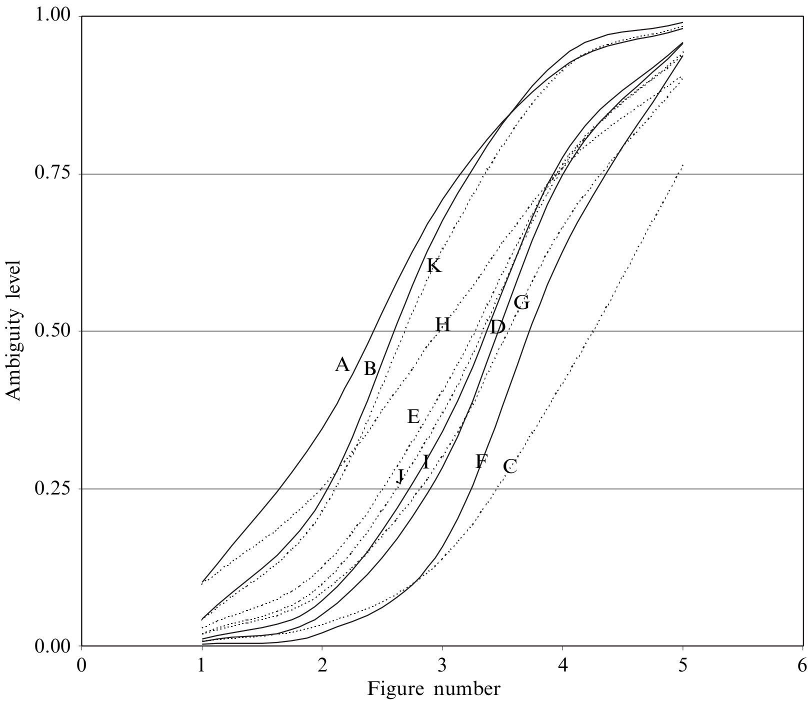


Figure 6. Logistic regression functions fitted to the pooled data of experiment 3 for each series separately. Dotted lines represent the nonliving series; continuous lines represent the living series (see figure 4).

resulting functions are steeper around the point of pure ambiguity as compared with the functions for the geometric series. The steeper the function the more it suggests two discrete categories. This suggests in turn that only two meanings may be assigned to living series, while more intermediate forms can exist within nonliving series.

4.2.2 *Manipulations.* A 2×2 repeated-measures analysis with Instruction (outside–in and inside–out) and Configuration (LR and RL) as repetition factors on the data of experiment 3 showed a main effect of Configuration ($F_{1,54} = 9.246$, $p < 0.0001$) and an interaction between Instruction and Configuration ($F_{1,54} = 8.241$, $p < 0.01$); no effect of Instruction could be established ($F_{1,54} = 2.650$, $p > 0.05$). Again, the covariate Ambiguity level shows a significant contribution (Wilks's $\Lambda = 0.631$, $p < 0.0001$). As before, a main effect of Configuration (LR > RL) indicates a preference for extremes placed on the right of the ambiguous figure. An interaction between Instruction and Configuration signifies a preference (see figure 3c) for comparison to the right coinciding with the preference for right-pointing arrows in experiments 1 and 2.

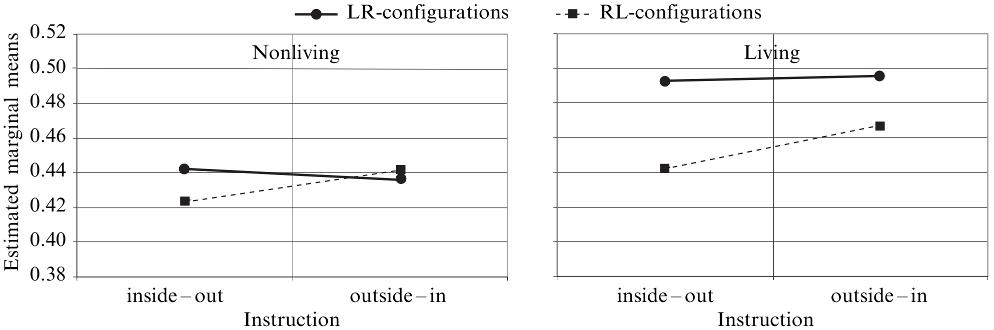


Figure 7. Results of experiment 3. The results of experiments 1 and 2 as displayed in figure 5 are essentially reproduced.

4.2.3 *Nonliving versus living series.* When the collection of series was divided into nonliving versus living ones, according to the segregation that resulted from experiment 2, it once again showed that the preference for right extremes is limited to the living series only (see figure 7). The above 2×2 repeated-measures analysis with Instruction (outside – in and inside – out) and Configuration (LR and RL) as repetition factors on the living series (series A, B, D, F, and I in figure 1), showed a main effect of Configuration only ($F_{1,24} = 11.142$, $p < 0.01$). No effect of Instruction occurred ($F_{1,24} = 2.77$, $p > 0.05$) and no interaction between Instruction and Configuration could be established ($F_{1,24} = 2.518$, $p > 0.05$). As in the previous experiments, this stands in contrast with the analysis done on the nonliving series only (series C, E, G, H, J, and K): a significant interaction effect occurred between Instruction and Configuration ($F_{1,29} = 6.582$, $p < 0.05$), but no main effect of Configuration ($F_{1,29} < 1$), nor of Instruction ($F_{1,29} < 1$). The covariate Ambiguity level was significant for both the living series (Wilks's $\Lambda = 0.225$, $p < 0.001$) and the nonliving ones (Wilks's $\Lambda = 0.612$, $p = 0.013$). Note that the influence of Ambiguity level is much smaller for nonliving figures than for living ones.

The effect of Configuration found for figures of living objects once again reflects a larger impact of right extremes on the middle figures, independently of Instruction. For nonliving figures, however, the results are somewhat more complex; these figures are most influenced by a comparison to the right—subjects preferred the extreme that was involved in a rightward comparison, no matter whether the extreme on the left came first and they moved rightwards to the ambiguous figure, or vice versa.

By replacing the instruction to draw right-pointing arrows of experiments 1 and 2 by an instruction to circle the preferred extreme in experiment 3, the effect found for nonliving figures was somewhat diminished (the F-value drops from 17.901 in experiments 1 and 2 to 6.582 in experiment 3). This indicates that the explanation based on right-pointing arrows, given for the nonliving figures in section 3.2, cannot have been the whole story. Drawing right-pointing arrows accounts for a reasonable percentage of the F-value, but it turns out to be based on comparisons to the right also.

4.2.4 *Alternative distinctions of the series.* Nonliving figures versus figures of living objects was the division that emerged from experiments 1 and 2. However, alternative divisions are possible, and it would strengthen our division into nonliving and living based on experiments 1 and 2 if it also turns out to be preferable above other distinctions in experiment 3. Various distinctions are made in the literature. Besides nonliving versus living objects (Mehta et al 1992), also directionality (Bernstein and Cooper 1997), and geometric versus verbalisable (Nebes 1974) are distinctions that make sense according to figure 4. Directionality comprises facing forwards (series A, C, H, and K), facing sidewards (series D, I), or changing (series B, E, F, G, and J). Geometric versus verbalisable comprises series C, H, and K, versus series A, B, D, E, F, G, I, and J, respectively. A planned-comparisons test, however, shows that a distinction between living and nonliving objects explains the data best ($F_{2,51} = 6.703$, $p < 0.01$), followed by geometric versus verbalisable ($F_{2,51} = 3.559$, $p < 0.05$), and finally directionality shows an insignificant distinction ($F_{2,50} = 1.680$, $p > 0.05$).

5 General discussion

The combined results of the reported experiments provided us with useful data on the ambiguity levels of ambiguous figures. We feel these normative data may be of use for others as well. The resulting normative data are useful for our purposes as outlined in section 1, but may be useful more generally in other contexts too. For example, one could need stimuli that are somewhat ambiguous but also slightly biased towards one interpretation (eg for priming studies).

The results of the three experiments reported here suggest that two distinctive types of ambiguous (reversible) figures exist: nonliving and living. For the figures of living objects, a differential influence of the flanking side was found on the interpretation of the ambiguous figure in the middle. In particular, the flanker to the right exerts the greatest influence on the interpretation of the ambiguous middle figure. For nonliving figures the story is more complex; the right flanker exerts the greatest influence only in the condition where the subject is instructed to judge the triplets from inside out: to compare the middle figure to the extremes. In contrast, in the condition where the subject is instructed to compare the extremes with the middle figure, ie outside in, the leftmost extreme exerts the greatest influence on the middle figure. Irrespective of instruction type; this means that subjects prefer the extreme involved in a rightward comparison.

The distinction between nonliving and living objects in general is in agreement with other findings in the literature (eg Mehta et al 1992). It is also in agreement with the distinction Strüber and Stadler (1999) found for ambiguous figures in particular. Strüber and Stadler found reversibility of semantic figures (like Jastrow's duck – rabbit), more so than of abstract figures (like the Necker cube), to be dependent of top – down influences. They hypothesised that the reversibility of abstract figures, in contrast, is orchestrated by satiation of neural detectors or channels. Satiation theory, originally proposed by Köhler (1940) and more recently advanced by Hock et al (1996), provides an explanation for perceptual reversal of ambiguous figures due to an automatic bottom – up process of neural fatigue.

Would top – down influences provide us with a satisfactory explanation for our findings with figures of living objects, as it did for Strüber and Stadler? For semantic-ambiguous figures, Strüber and Stadler proposed that top – down influences play a major role in reversals since these figures require a reconstrual of meaning. Our results agree with their findings; the sigmoid functions that could be mapped onto the series suggest that, in comparison with the nonliving figures, figures of living objects can have either of two meanings but by and large no intermediates.

Would top – down influences also provide an explanation for our finding that, for figures of living objects, the rightmost extreme in a triplet is the most preferred interpretation of the middle figure? Matching of memory representations (among others) is one of the cognitive processes usually attributed to the top – down influences. Matching of memory representations makes sense as an explanation for our findings with figures of living objects. It appeared to us that viewing the images one after another might introduce a presentation-order effect causing a pattern previously perceived to persist (ie hysteresis; eg Kelso 1995), the very reason to swap the extremes in experiment 1. Now, when it is conceived that subjects will read three figures in a row 'as a sentence', ie from left to right, followed by a return to the ambiguous middle figure in order to judge it, then the most recent 'reading history' consists of the rightmost figure.

This way the rightmost figure of a triplet constitutes the most recent memory representation to which the middle figure will be matched.

Alternatively, McConkie and Rayner (1976) and Osaka and Oda (1991) argue that reading direction favours an attentional bias that is directed forwards, ie to the right. This also favours the extreme to the right. But these authors did not consider the flanker test nor did they study pictorial stimuli.

Explanations based on reading direction also make sense of the relationship that was found between ambiguity and preference; with increasing ambiguity of the middle figure, increasing preference for the rightmost figure was found. Now, when it is assumed that the rightmost figure constitutes the most recent memory representation or when attention is directed forward, it seems reasonable that under increasing uncertainty (ambiguity of the middle figure) the interpretation of the middle figure is increasingly influenced by the contents of the rightmost flanker.

Before jumping to an explanation based on top–down effects for the figures of living objects, at least the alternative explanation based on satiation needs to be ruled out. This alternative explanation, however, can be discarded by the positive relationship that was found between preference and ambiguity. This relationship implies that the utmost preference for the rightmost figure in a triplet is found when the middle figure is maximally ambiguous, in other words, when the perceptual overlap between middle figure and its flankers is *minimal*. This is not what an explanation based on neural fatigue would predict. Maximal neural fatigue is to be expected when much the same perceptual channels are addressed by adjacent figures, that is when two successively inspected figures have maximal perceptual overlap, eg EL and E1 in figure 1. Hence, neural fatigue would predict the strongest preference when a minimally ambiguous figure (eg E1) is placed in the middle of a triplet,[3] and not, as we have found, when a maximally ambiguous figure (eg E3) is placed in the middle.

Moreover, in our experiments we reversed the extremes. Reversing the extremes causes opposite fatigue patterns, which should have leveled each other out in the analyses, resulting in no relationship at all, instead of the linear relationship between preference for rightmost figures and ambiguity that we have found.[4]

Unfortunately, the same lines of reasoning force us to discard a neural-fatigue explanation for our findings with nonliving (or what Strüber and Stadler call abstract) figures. Rightward comparisons are preferred for this type of figure. This means that when two successive figures in a triplet are inspected from left to right, the flanker involved in this rightward comparison is preferred, be it the first figure to be inspected or the second. Just as with the figures of living objects, this preference is subject to a positive linear relationship between preference and ambiguity, ie maximal preference with minimal overlap of the middle figure and the extreme, ruling out explanations

[3] Moreover, as a consequence of neural fatigue the flanker with minimal perceptual overlap, ie figure ER in figure 1, would in this case be preferred. For E5 in figure 1, a figure with a comparable ambiguity level to E1, the situation would be reversed, and EL would be preferred. With comparable ambiguity levels then, the preferred flankers can be on either side of the middle figure, not necessarily the right side.

[4] This can be understood by looking at figure 1. Stimulus E1 in figure 1, for example, has large perceptual overlap with its leftmost extreme EL. According to the satiation explanation, then, ER would have been the preferred interpretation of E1 when a triplet is viewed in the following order: EL – E1 – ER. When E2 is viewed after EL, the probability of an ER interpretation decreases, because the perceptual overlap between the leftmost figure EL and E2 is smaller. This probability decreases even more with E3 and reaches a minimum at E5. For opposite viewing orders, ER – E1 – EL, the overlap would increase from E1 to E5. Hence, while in LR configurations the probability decreases, it increases in RL configurations, leveling each other out. As a result, the preference for rightmost figures could never have peaked at maximal ambiguity, in contrast with what we have found.

based on perceptual overlap. Moreover, what applies to figures of living objects, also applies to nonliving figures; reversing the extremes should have leveled out the fatigue patterns, causing no relationship at all.

Strüber and Stadler's attribution to neural fatigue, hence, fails to provide a satisfying explanation for our findings with nonliving figures. However, a tentative alternative explanation based on bottom – up processing can be found in the literature. Nebes (1974) distinguished between geometric and verbalisable figures; he concluded that when two geometric figures are compared, the one in the left visual field exerts greater influence. No such effect was found with verbalisable figures. Nebes's findings with geometrical figures might apply to our data: when a rightward comparison is made, the decision whether or not a close resemblance exists between two adjacent figures is taken when the eyes are fixated on the figure to the right; at that very moment the figure on the left is located in the left visual field. This can be seen by inspecting those situations in figure 3 where a rightward comparison is made. The arrowheads in figure 3 can be taken to symbolise the endpoint of a comparison; when looking at these endpoints the starting point of the comparison is located in the left visual field.

Here again, the linear relationship between ambiguity and preference makes sense; the more uncertain it is, the more influence the content of the left visual field can have. This applies, however, only to outside – in conditions in figure 3 where the ambiguous figure is under focus and the extreme is in the left visual field, but not to inside – out conditions where the situation is reversed. In these latter situations, the ambiguous middle figure resides in the left visual field and interpretation of the flanker concurrently under focus is maximally certain. Maybe this explains why the linear relationship between ambiguity and preference is much smaller for nonliving figures than it is for living ones.

These are all tentative explanations and they leave some important questions open. Why, for example, would it be that instructions to inspect a triplet inside – out or outside – in do not matter for figures of living objects—for these figures the right flanker is preferred either way? Do subjects ignore these instructions and follow a reading order? Probably not, since inspection order does matter for the nonliving figures. Our data might be taken to suggest that inspection orders are lost at the time the information reaches higher processing levels. But, unfortunately, this issue can only be solved by checking for the direction of eye movements, and since our experiments took place under free-viewing conditions, we were not able to check the direction of eye movements.

Apart from controlling eye movements, it might have been informative to have controlled the inspection time. Triplets of living but unambiguous semantic figures have been studied by Hommel (1995) in the classical Eriksen flanker paradigm (Eriksen and Eriksen 1974). In this paradigm, subjects must focus on the middle figure and no eye movements are allowed. Since they must react as soon as possible to the identity of the middle figure, very short inspection times occur in this paradigm. This task could be done without the need to identify the flankers. However, Hommel's results rather diverge from ours. For close flankers his results indicated that the *left* flanker asserts the largest influence on the identity of the middle figure; for flankers farther away this effect disappeared. Are these divergent findings due to differences in inspection times, differences in instruction, or differences in stimuli, or other unknown variables?

Questions remain, but our results suggest that further exploration along these lines will enrich our understanding of the nature of ambiguous figures.

Acknowledgments. This research was supported by KU Leuven research grant F/98/048 to the first author. The authors would like to thank Gert Storms for his useful suggestions and Stefaan Tibau for his assistance in data collection.

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ISSN 0301-0066 (print) ISSN 1468-4233 (electronic)

PERCEPTION

VOLUME 33 2004

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