Seeing and imagining the "same" objects in unilateral neglect

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Abstract – Dissociations between perceptual and imaginal neglect are typically investigated by using very different tasks (e.g. visual target cancellation vs. place descriptions). Here we report patients' performance on imaginal and perceptual tasks which shared identical stimuli and procedure, except for the modality of stimulus presentation. In different tasks, participants either saw towns/regions on a map of France or heard their names, and pressed one of two keys according to the stimulus location (left or right of Paris). Neglect patients as a group were less accurate for left-sided stimuli in both modalities, but on single case analysis only one patient with perceptual neglect had asymmetrical imaginal accuracy. These results confirmed that imaginal neglect is relatively rare, and is usually associated with perceptual neglect. Perceptual neglect resulted more frequent and severe than imaginal neglect, also when assessed using strictly comparable tests, consistent with the exogenous orienting bias typically observed in these patients.

Keywords: visual perception, mental imagery, scene exploration, visual attention

1. Introduction

Since the seminal observation by Bisiach and Luzzatti (1978), neglect for the left side of mental images has raised important issues concerning the "spatial" character of visual mental imagery. In particular, the study of the relationships of neglect for visually perceived objects to neglect for imagined objects can shed light on the nature of these deficits and on the normal processes implicated in the exploration of a visual scene and of a endogenously generated mental image.

For example, the original hypothesis of an amputation of the mental representation of space in imaginal neglect (Bisiach *et al.*, 1981; Bisiach & Luzzatti, 1978) would predict similar frequency of perceptual and imaginal neglect, because both would result from "a representational map [of space] reduced to one half" (Bisiach et al., 1981, p. 549). Contrary to this prediction, subsequent studies (reviewed in Bartolomeo, 2002) found that perceptual neglect often occurs without imaginal neglect[1]. However, the interpretation of these results is complicated by the possibility that some patients might provide symmetrical descriptions of places only because they are recalling items from their verbal semantic memory, without employing visual imagery abilities (Rode *et al.*, 2004). Such an occurrence could in principle explain the lesser frequency of imaginal neglect as compared to visuospatial neglect. To address this issue, a response time (RT) test with geographical items was devised, which strongly encouraged the use of visual mental imagery (Bartolomeo *et al.*, 2005). Patients were asked to conjure up a visual mental image of the map of France (see Rode et al., 2004) and to state, by pressing a left- or a right-sided key, whether auditorily presented towns or regions

[1] In rare cases, imaginal neglect can occur without perceptual neglect (see, e.g., Ortigue *et al.*, 2001), thus raising the possibility of separate underlying mechanisms for the two forms of neglect (see Bartolomeo, 2002, for discussion of this issue).

were situated to the left or right of Paris on the imagined map[2]. Patients with perceptual neglect were slower for left than for right imagined locations, but single-case analysis showed that only two patients with perceptual neglect had a reliable response time asymmetry on the geographical task. These results confirmed the relative rarity of imaginal neglect as compared to visual neglect (Bartolomeo, 2002). It remains, however, unclear how comparable are the outcomes of such diverse measures as performance on paper-and-pencil tasks and imaginal tasks.

To deal with this methodological problem, and to compare patients' visual and imaginal performance on a firmer basis, we developed a new perceptual RT task, aiming at being as close as possible to the imaginal RT task. Participants saw an empty map of France on the computer screen, and had to respond by keypress to visual targets appearing on the map, in locations corresponding to the places presented auditorily during the imaginal task. In this way, possible differences in patients' performance on the two geographical tasks (henceforth, the imaginal and the perceptual task) are more likely to reflect differences in the underlying deficits rather than purely task-related differences.

2. Methods

2.1. Participants

Twenty-five right-handed patients with unilateral lesions in the right hemisphere consented to participate in this study. Visual neglect was assessed by using standardized paper-and-pencil tests (see Azouvi *et al.*, 2002; Bartolomeo & Chokron, 1999 for detailed test description). Sixteen of the patients showed signs of left visual neglect (henceforth N+ patients; mean age,

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[2] Participants are encouraged to use imagery abilities on this tasks because in propositional judgments geographical items are rarely understood in terms of "left" or "right".

58.88 years; range 45-73); the nine remaining patients had no sign of visual neglect (N-patients; mean age, 56.56 years; range 49-74). Twelve right-handed participants free of cerebral disease also participated in the study (mean age, 57 years; range 49-74). No subject had participated to the previous Bartolomeo et al. (2005) study. Table 1 reports the demographic and clinical characteristics of patients.

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Table 1 about here

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2.2. Description from memory of a map of France

Participants were invited to imagine a map of France “like the one shown in TV weather forecasts”, and to name as many geographical locations as possible which they imagined “seeing” on the map. Responses given during two minutes were collected and classified as left- or right-sided depending on the items’ location with respect to the Paris meridian (Rode et al., 2004). Items situated near the meridian, or items with ambiguous laterality (e.g., the Seine river), were excluded from analysis.

2.3. Imaginal RT task

We used the geographical RT task developed by Bartolomeo et al. (2005). Twenty pairs of geographical locations (names of towns and regions of France) were selected. Each pair consisted of items situated east and west of Paris, in a roughly symmetrical fashion. Stimuli were presented on a portable PC using the SuperLab software. Participants were comfortably seated and wore a pair of headphones. They had their right hand on the computer keyboard, with their index and ring fingers placed on, respectively, the “*k*” and the “*;*” keys of the American keyboard. Before starting, participants were asked to imagine a map of France. Then, on each trial they heard the words “Paris” and, after 200 ms, another French town or region (e.g., “Bordeaux”). Participants were instructed to press the “*k*” key if the second stimulus referred to a location left of Paris, or the “*;*” key if the stimulus indicated a location right of Paris. The intertrial interval was set to 3 seconds starting from the participant’s response to the previous trial. A maximum of 5 sec was allowed for response on each trial. Stimuli were given in a random sequence, preceded by six additional practice items. To avoid responses to particular stimuli becoming automatic with practice, each target was presented only once. Eye and head movements were not restricted. Accuracy and response times were recorded.

2.4. Perceptual RT task

Participants sat in front of a PC computer monitor at a distance of ~50 cm. A white, empty map of France was displayed on a black background. For each trial, a black dot 8-mm in diameter appeared in the central location corresponding to Paris for 3sec, and was replaced immediately afterwards by a lateralised target. Targets consisted of red dots 8-mm in diameter, which were displayed on the map one at a time, at the locations corresponding on the map to the equivalent items used in the imaginal task. Also the response keys were the same as for the imaginal task. As soon as the target appeared, subjects had to respond by pressing the left-sided or the right-sided key depending on whether the red dot was located left or right of the black dot. Targets remained on until response or for a maximum of 5 sec. Both speed and accuracy of response were emphasized. Eye or head movements were not restricted.

2.5. Response bias RT task

Response keys for the RT tasks were lateralised in order to keep the task easy for patients. This raises the issue of a potential directional bias in motor responses, with left keys evoking slower responses than right keys independent of stimulus location. To control for this possibility, a further task used the same response keys with simple verbal instructions (“left” or “right”). The intertrial interval was set to 1 second. There were 12 left and 12 right stimuli, given in random order.

3. Results

3.1. Description from memory

Control participants reported an average of 14.9 ± 5.9 left-sided items and of 16.5 ± 6.6 right-sided items. No individual control reported more items on one side or another on this task (binomial test, all ps > 0.09). Patients’ results are displayed in Table 1. Seven brain-damaged patients had asymmetric performance. Two neglect patients and 4 non-neglect patients reported more items on the *left* than on the right imagined side. Only one neglect patient (N+13) reported more items on the right side than on the left side, consistent with the phenomenon of imaginal neglect.

3.2. RT tasks

3.2.1. Group analysis

Reponses to practice trials and RTs beyond 2.5 SD around each participant’s mean were excluded from the analysis. The trimming procedure led to the exclusion of 3% of the responses. A repeated-measure analysis of variance (ANOVA) was conducted on mean correct RTs (Fig. 1) with group (controls, N+ patients and N- patients), task (imaginal, perceptual and response bias) and side (left, right) as factors.

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Fig. 1 about here

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All the principal effects were reliable (group, $F(2, 32) = 24.32$, $p<0.0001$; task, $F(2, 64) = 6.11$, $p = 0.003$; side, $F(1, 32) = 41.93$, $p < 0.0001$), as was their interaction ($F(4, 64) = 8.38$, $p < 0.0001$). As it is evident from Fig. 1, controls and N- patients as a group did not show any reliable asymmetry of performance on any task (Fisher's LSD, all ps > 0.11). N+ patients, on the other hand, responded 715 ms slower to left-sided than to right-sided visual stimuli ($p < 0.0001$)[3]. N+ patients had marginally significant tendencies in the same direction on the motor bias test (left minus right, 122 ms, $p = 0.067$) and on the imagery test (114 ms, $p = 0.074$).

A further ANOVA was applied to the arcsin-transformed proportions of correct responses with the same group, task and side factors as for the RT analysis (Fig. 1). Again, all the principal effects were reliable (group, $F(2, 34) = 8.89$, $p < 0.0001$; task, $F(2, 68) = 54.48$, $p < 0.0001$; side, $F(2, 34) = 4.37$, $p = 0.02$). The three factors interacted ($F(4, 68) = 8.78$, $p < 0.0001$), because neglect patients' near-chance performance for left stimuli on the perceptual task was worse than performance for any other condition and group (Fisher's LSD, all ps < 0.003). Within each group and task, the only significant left-right difference in accuracy stemmed from neglect patients' performance on the perceptual task (mean correct responses: left, 54%; right, 88%; $p < 0.0001$) and on the imaginal task (left, 72%; right, 82%; $p = 0.01$).

[3] Neglect patients also responded slower than the other groups to right-sided targets, consistent with the presence of non-lateralized attentional impairments in neglect (see Bartolomeo & Chokron, 2002, for review and discussion).

3.2.2. Multiple single-case analysis

To explore the performance of individual patients, each RT was normalized by dividing it by the average RT for each patient on each task. Scores of laterality were calculated for each patient and task (normalized left – right RTs), and plotted along with the 95% inferential confidence intervals (Tryon, 2001) of the left-right difference for each patient. In this way, one can be 95% confident that intervals which do not cross the horizontal axis at 0 indicate a rightward bias (for positive values) or a leftward bias (for negative values). For each patient, non-overlapping intervals indicate a difference in bias between the two tasks. Results (Fig. 2) showed that although several patients showed a rightward RT bias on the imaginal task, in no patient was this bias independent of motor bias. On the other hand, on the perceptual task patients N+1 and 7 demonstrated a rightward bias that clearly exceeded the motor bias.

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Fig. 2 about here

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Binomial tests were used to compare accuracy of responses for left and right-sided stimuli. Controls and non-neglect patients showed no reliable asymmetry on the geographical tasks, whether perceptual or imaginal. Only one neglect patient (N+4), gave more correct answers for the right side than for the left side ($p=0.008$) (Table 1) on the imaginal task. Curiously, when describing the map of France from memory this same patient had not been able to spontaneously recall any town on the right side. In contrast to the results of the imaginal task, on the perceptual task 6 neglect patients (4, 7, and 12-15) were more accurate for right-sided than for left-sided visual items (all $ps < 0.05$) (Table 1).

4. Discussion

The relationship between visual perception and visual mental imagery is a matter of intense debate in cognitive neuroscience (see Pylyshyn, 2002 and the following discussion). One influential model stipulates that visual mental images are spatially displayed on some of the same brain areas that sub-serve visual perception, such as the occipital visual areas (Kosslyn *et al.*, 2006). Evidence from brain-damaged patients showing dissociations between perceptual and imagery abilities (reviewed in Bartolomeo, 2002) is not consistent with this model. However, some of the described dissociations could result from the use of different tasks to test perception and imagery. Some patients might find it easier to solve perceptual than imagery tasks, which are often demanding in terms of working memory; these patients might therefore demonstrate apparently selective imaginal deficits. Other patients might use intact propositional knowledge to perform putatively imaginal tasks, and thus show apparently selective perceptual impairment. The present study addressed this methodological issue in the domain of unilateral neglect, by comparing patients' performance on imaginal and perceptive tasks which used stimuli that were identical in every respect, except for the modality of presentation, and identical motor responses.

In a previous study using the same imaginal paradigm (Bartolomeo et al., 2005), two patients with visual neglect had a greater RT asymmetry on the geographical task than predicted by the response bias task. In the present study, only one patient, showing signs of visual neglect (N+13), had such an imaginal asymmetry. Another patient (N+4) might have demonstrated a similar asymmetry, but he was only able to produce 3 correct responses for left-sided items; this resulted in large CIs, with consequent statistical indeterminacy. For both these patients, however, the imaginal RT bias was not independent of a putative response bias. Thus, while an imaginal impairment resulting in slower processing of left visual images

(Bartolomeo et al., 2005) cannot be excluded in these patients, it is equally impossible to conclude for such an imaginal deficit on the basis of the present results.

Response accuracy on the imaginal task was also significantly asymmetric in patient N+4, with more correct responses for right-sided than for left-sided imagined stimuli, thus also suggesting an imaginal impairment. In this sense, patient N+4 in the present study demonstrated a different pattern of results from two previously explored patients, who had symmetrical accuracy but RT slowing for left-sided stimuli (see patients N+1 and N+4 in Bartolomeo et al., 2005). This discrepancy may either be explained by differences in speed-accuracy tradeoffs, with some patients having slower responses for stimuli whose localisation they are unsure, or it may reflect genuinely different imaginal deficits. On the map description, patient N+4 produced no right-sided items and five left-sided items. This underlines the difficulties of performing the map description task for some patients.

The principal purpose of the present study was to evaluate imaginal and perceptual performance on comparable RT tasks in an unselected sample of patients with unilateral right-hemisphere lesions. The results of this comparison are clear-cut. The perceptual task elicited a much greater asymmetry of performance on both RTs and response accuracy than the imaginal task did. Consistent with their performance on the paper-and-pencil neglect battery, neglect patients were slower and less accurate for left-sided visually presented geographic stimuli than for their right-sided counterparts. This result stands in sharp contrast to patients' performance on the imaginal task, which was much less asymmetric. These findings add to the abundant evidence showing that neglect is more frequent and severe for "real" visual stimuli than for mental images (see Bartolomeo, 2002). In most cases, neglect appears to affect patients' interaction with the external world, rather than putative mental representations of space (Urbanski & Bartolomeo, 2008).

Even if eye movements were not restricted, stimuli presented left of fixation were probably harder or longer to process for hemianopic patients on the perceptual task. However, visual field defects alone are unlikely to fully account for the RT asymmetry, because the 4 neglect patients without hemianopia still showed a 470-ms left-right difference ($t(3)=4.25$, $p=0.02$). According to models postulating an equivalence between visual perception and visual mental imagery, visual field defects should impair performance on perceptual and imagery tasks in a similar manner (Butter *et al.*, 1997). This was clearly not the case in the present results, which demonstrated a much greater asymmetry for perceptual than for imagined spatial items, and thus provided a strong challenge to this class of models of visual mental imagery.

In conclusion, the present study demonstrates that, even when performing highly comparable perceptual and imaginal task, right-brain damaged patients are much more likely to neglect real visual items than imagined scenes, consistent with the bias of exogenous orienting of attention typically observed in these patients.

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Table 1. Demographical and clinical characteristics of patients, with their performance on visuospatial tests, the number of items reported when describing from memory the map of France and the number of correct responses on the imaginal and perceptual RT tasks.

Patient	Sex / age / years of schooling	Days since onset	Aetiology	Locus of lesion	Visual Field	Line bisection 1 (% deviation for 200mm / 50mm lines) (Azouvi et al., 2002)	Line bisection 2 (cumulative % deviation) (Bartolomeo & Chokron, 1999)	Bells cancellation (number of left/right hits, max 15/15) (Azouvi et al., 2002)	Overlapping figures (number of left/right hits, max 10/10) (Azouvi et al., 2002)	Landscape drawing score (Azouvi et al., 2002)	Map description (left/ right)	Imaginal RT task (left/right correct responses, max 20/20)	Perceptual RT task (left/right correct responses, max 20/20)
N+1	M / 62 / 10	173	H	MCA	LHH	+52* / +2	+18.0*	4 / 15*	9 / 10	4*	10 / 13	15 / 15	16 / 19
N+2	F / 61 / 10	38	I	MCA	LHH	+45* / +8	+13.0*	6 / 13*	6 / 10*	2*	6 / 6	18 / 17	15 / 18
N+3	M / 52 / 12	413	I	MCA, ACA	LHH	+8.5* / -8	+31.6*	7 / 12*	10 / 10	1*	2 / 5	12 / 16	19 / 20
N+4	M / 60 / 12	148	H	IC, Th	LHH	+50* / +30*	+19.0*	0 / 15*	10 / 10	4*	5 / 0†	3 / 13†	4 / 14†
N+5	F / 54 / 8	168	I	AchA	normal	+7.5* / 0	+10	9 / 15*	9 / 10	0	4 / 6	11 / 11	15 / 20

Table 1 (continued)

N+6	M / 73 / 10	227	I	MCA (PO)	normal	+8* / +4	+5.71	9 / 15*	10 / 10	0	23 / 15	16 / 18	16 / 20
N+7	M / 65 / 8	81	I	MCA	LHH	+69* / +22*	+14.5*	0 / 14*	2 / 9*	4*	4 / 6	8 / 11	1 / 18†
N+8	M / 72 / 14	93	H	P	LHH	+55* / +2	+15.4*	10 / 13*	0 / 10*	1*	10 / 8	18 / 19	7 / 14
N+9	F / 60 / 11	372	I	MCA	normal	+9* / -10	+25.9*	0 / 14*	9 / 10	0	7 / 8	16 / 17	16 / 19
N+10	M / 52 / 17	40	I	MCA	LHH	+10* / 0	+14.5*	6 / 14*	10 / 10	1*	17 / 8†	18 / 18	18 / 19
N+11	M / 51 / 10	70	I	MCA	normal	+8.5* / 0	+13.0*	0 / 14*	8 / 10*	1*	9 / 5	16 / 14	18 / 17
N+12	M / 57 / 9	206	I	PCA	LHH	+60* / +4	+60.4*	0 / 13*	9 / 9	3*	3 / 9	12 / 16	7 / 20†
N+13	M / 72 / 12	65	I	MCA	LHH	+11* / +8	+11.4*	0 / 12*	3 / 9*	1*	15 / 31†	13 / 19	0 / 10†
N+14	F / 58 / 11	106	I	WM, BG	LHH	+8.5* / +4	+11.6*	6 / 14*	6 / 10*	1*	9 / 9	16 / 18	0 / 17†
N+15	M / 45 / 12	444	H	IC, Th	LHH	+59.5* / +4	+40*	0 / 13*	8 / 10*	4*	8 / 15	18 / 20	10 / 18†

Table 1 (continued)

N+16	F / 48 / 11	32	I	MCA	LHH	+9* / 0	+25.9*	0 / 14*	9 / 10	0	1 / 2	19 / 19	12 / 18
N-1	M / 52 / 11	573	I	MCA	normal	+1.5 / 0	+9.28	15 / 15	10 / 10	0	3 / 4	17 / 18	19 / 20
N-2	F / 51 / 12	364	I	MCA	normal	+1 / -4	+2.85	15 / 15	10 / 10	0	8 / 4	9 / 12	18 / 19
N-3	F / 49 / 11	79	I	MCA, ACA	normal	+2 / 0	+10.2	14 / 15	10 / 10	0	10 / 3†	18 / 17	15 / 20
N-4	F / 74 / 17	70	I	MCA	normal	+1 / -2	+9.52	15 / 15	10 / 10	0	14 / 19	11 / 16	17 / 19
N-5	M / 63 / 8	40	H	IC, BG	normal	+2.5 / -6	+5.71	15 / 15	10 / 10	0	14 / 6†	17 / 20	19 / 18
N-6	M / 58 / 12	235	I	MCA	normal	+0.5 / -2	+10.4	15 / 15	10 / 10	0	16 / 8†	15 / 15	19 / 19
N-7	M / 57 / 10	1250	I	MCA	normal	+1.5 / +12*	-3.80	14 / 13	10 / 10	0	10 / 5	16 / 19	18 / 18
N-8	M / 55 / 9	452	I	MCA	normal	-0.5 / -2	+5.95	13 / 15	10 / 10	0	8 / 2†	16 / 15	19 / 19
N-9	M / 50 / 12	298	H	IC, Th	normal	-3 / -4	+10.9	14 / 14	10 / 10	0	9 / 7	15 / 16	19 / 19

Table 1 (continued)

I, ischemic; H, hemorrhagic; MCA, middle cerebral artery territory; ACA, anterior cerebral artery territory; PCA, posterior cerebral artery territory; AchA, anterior choroidal artery territory; P, parietal; O, occipital; IC, internal capsule; Th, Thalamus; BG, basal ganglia; WM, white matter. LHH, left homonymous hemianopia. For line bisection, positive values indicate rightward deviations, negative values indicate leftward deviation. Asterisks denote pathological performance. † $p < 0.05$, binomial test.

Figure legends

Figure 1. Response times and percentage of correct responses (in parentheses) of normal controls and of right-brain damaged patients with or without visual neglect for left-sided items (hatched bars) and right-sided items (empty bars) on the RT tasks. Error bars denote 95% confidence intervals.

Figure 2. Laterality scores of each individual patient on the RT tasks. Positive values, rightward bias; negative values, leftward bias. Error bars denote 95% inferential confidence intervals. Patients N+13 and 14 were not able to detect any left-sided targets on the perceptual task, thus their laterality scores could not be computed for this task.

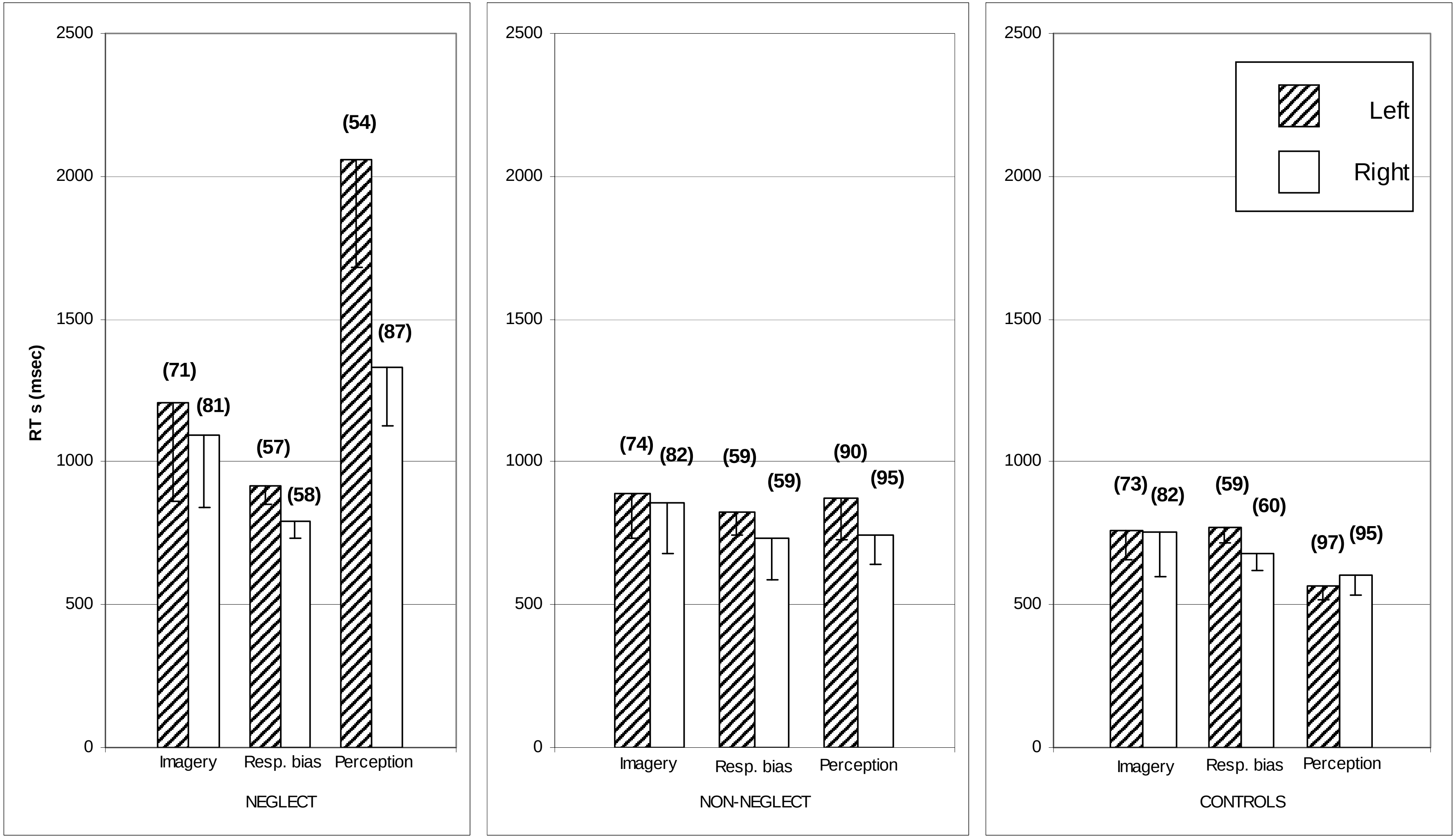
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Fig 1

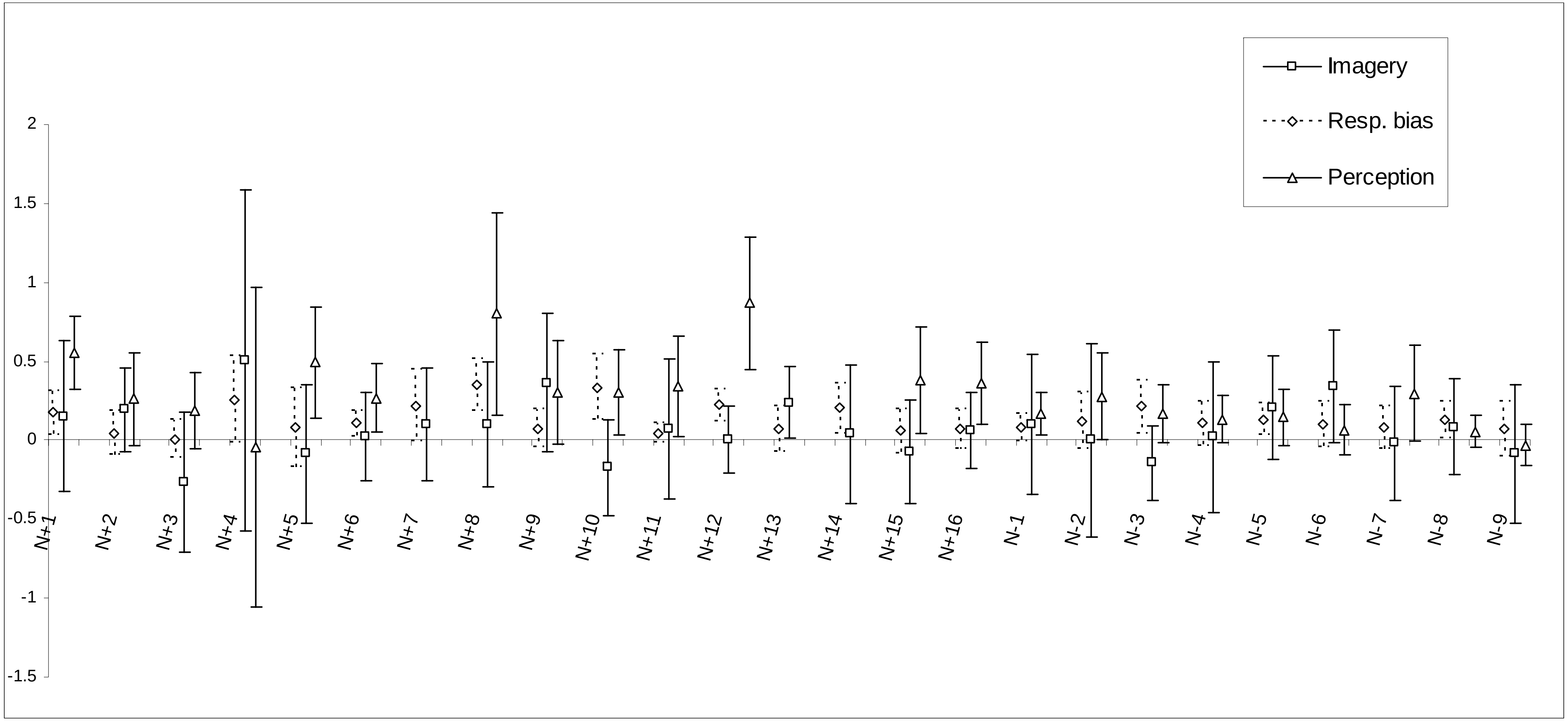
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Fig 2