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Perceptual salience of global structures and the crowding effect in amblyopia

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Abstract Background: The crowding effect is a perceptual phenomenon in which the performance is reduced when a target is surrounded by other objects. The present study investigated the perceptual salience of global structures and the crowding effect in amblyopia. Methods: Chinese characters were used as stimuli. The results showed that the crowding effect was significantly reduced in amblyopia when the target was surrounded by global structures. Conclusion: The present study suggests that the perceptual salience of global structures is reduced in amblyopia.

Keywords: Amblyopia, Crowding effect, Global structures, Perceptual salience, Reaction time
Introduction
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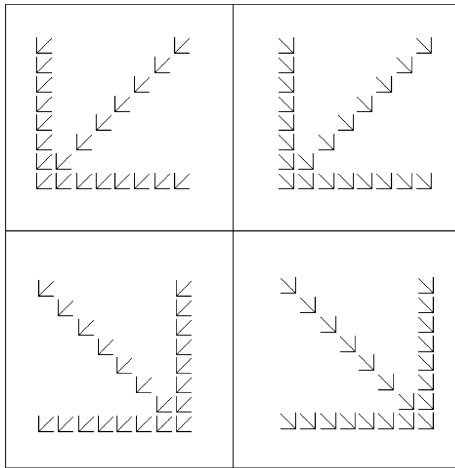


Fig. 1. Pattern of arrows in the grid. The arrows are arranged in a square grid.

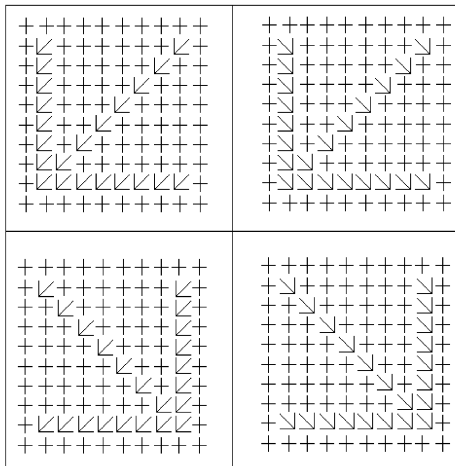


Fig. 2. Pattern of arrows in the grid. The arrows are arranged in a square grid with a central cross.

We recorded a series of ... We recorded a series of ... We recorded a series of ...

¹ M. de ... M. de ... M. de ...

The ... The ... The ...

Materials and methods

Subjects

The ... The ... The ...

Stimuli

The ... The ... The ...

Table 1. Values of ...

Observer	Age (years)	Sex	Eye	R	Ac
H.L.	5	F	OD	0.25	20/15
			OS	+3.25/+1.00	60
L.H.	10	F	OD	+0.75	20/20
			OS	+5.75/+1.50	115
X.K.	7	F	OD	+1.50/+0.50	100
			OS	+7.00/+0.50	110
X.Z.	12	M	OD	1.50	20/15
			OS	+1.00/+0.50	90
J.T.	12	M	OD	+2.00/+0.75	90
			OS	+1.00/+4.00	90
Z.Z.	6	F	OD	+1.00/+0.50	110
			OS	+5.00/0.75	85
C.F.	10	F	OD	+0.50/+0.75	185
			OS	+3.75/+2.00	180
S.M.	7	F	OD	+6.00/+0.50	60
			OS	+3.50	20/25
W.J.	8	M	OD	+0.50/+3.00	85
			OS	+1.75/+1.50	90
G.H.	13	F	OD	+3.00/+2.00	80
			OS	+2.00	20/20
M.X.	11	M	OD	PJA	20/15
			OS	+5.50	20/40
C.Q.	26	F	OD	PJA	20/15
			OS	+6.50/+1.00	90

P. ced e

Tee e e n e e n l e d a ± -fac s7 bec ds7, e fac s7 be r: G (l cal ele n e s7 ee, ed b a n bl c e e ll e e); G l bal (ds7c n a ± l bal l cal le el); a d C s7 s7 e c (e, l bal a d l cal le es7 a e c s7 s7 e c s7 s7 e). Eac al be a a 1000-n s7 a, bee a d e es7 e a ± a ± a c s7 l ca e d a e ce e ± es7c ee, c s7 0.4 0.3 c n s7 b e d, 0.58 0.43° ± s7 al a, le. A ± e a e 1000 n s7, e ± a c s7 s7 as7 e laced b es7 n l s7, c s7, es7 e d a e ce e ± e s7c ee a d s7 a e d s7 b e c s7 s7 ded. W le n a a, ± a s7 bec s7 ee e d de ± e e e a ± l bal l cal a s7 s7 e a a e b l c s7 ± a s7 b es7, e ± le s7 as7 a d a d le b a d e, a d le ± n d d le ± es7. T e es7 e a s7 e e ce ± s7 n l F, s7. l a d 2, e de ± es7 e a ± e e es7, a d e de ± e l bal a d l cal as7 s7 e e c e b a j a c e d a c s7 s7 b e c s7. F eac s7 n l s7 c d, ee ee 16. ac ce a s7 ± ll ed b 48 a s7 e b l c k ± e de ± ca ± e l bal l cal s7 a s7. S bec s7 e e e c a e d s7 d s7 c l a d a c a e l as7 s7 b l e. I e c l c d, s7 bec s7 ds7c n a e d e a s7 ± a s7 n all a es7 e d a e ce e ± e s7 al ± e l d. T ee ee 60 a s7, ± c e ± s7 12 ee ± ac ce. S n l ee es7 e d es7c ee l s7 b e c s7 n a d e a s7 s7 e. RT s7 a d e a s7 e e s7 b e c e d a e e a e d n e s7 e a al s7 s7 ± a a c e (ANOVA) G (n s7 s7 n la), E e (a n bl c s7 e ll e e), G l bal (l bal s7 l cal), a d C s7 s7 e c (c s7 s7 e s7 c s7 s7 e) as7 de e d e a a b l es7.

l cal a, l bal s7 n l [4.5% s7 2.3%, F(1,11)=6.07, P<0.03]. T e e e a c ± G, G l bal as7 s7, ± ca [F(1,11)=10.02, P<0.009] d e e fac a ee a a s7 ee, e e l cal c n a e d e l bal c d s7 e l cal ele n e s7 ee, ed b n e e a s7 d ee ce as7 b s7 e d be ee l bal a d l cal c d s7 e l cal ele n e s7, ed b s7 n la. T ee ee a s7 e l a b l e e a c s7 ± G, E e G l bal [F(1,11)=6.55, P<0.03], s7, s7, a e e e e c ± a n bl a d ee e al l bal/l cal es7 s7 s7 as7 s7 e e l cal ele n e s7 ee, ed b n a b s7 n la s7 a s7. P s7 - c a a l s7 s7 s7 ed a, ± e a n bl c e e, e a s7 e e n r ed s7 n l ee, e e l cal a, l bal c d s7, ee a s7 e a s7 es7 n la r ed s7 n l d d d ee be ee e l bal a d l cal c d s7 [F(1,11)=18.29, P<0.002]. M e e, s7 b e c s7 n a d e n ee s7 s7 d, l cal a, es7 e l cal ele n e s7 ee, ed b n a b s7 n la [F(1,11)=6.98, P<0.022], e e a s7 e a s7 e l bal a, es7 d d d ee be ee e c d s7 [F(1,11)=2.73, P>0.1]. F e n a l e e, ee, ee a s7 d d d ee be ee n - a d s7 n la r ed s7 n l e, r a d l es7 ± e e s7 b e c s7 de ± e d, l bal l cal s7 n l (P>0.2).

Results

E a s7

T e n e a e a s7 de e a c c d a e r, e Table 2. T ee a s7 ee, e ± e a n bl c a ± e e ll ee [4.6% s7 2.2%, F(1,11)=6.18, P<0.03]. S bec s7 n a d e n ee s7 s7 s7 e

Reac n s7

T e a e a e RT s7 ± c e c es7 s7 s7 n - a d s7 n la r ed s7 n l a e s7 Table 3. T e a a l s7 s7 ± RT s7 d c a e d s7, ± ca n a e e c s7 ± G, [F(1,11)=5.74, P<0.034], E e [F(1,11)=9.56, P<0.01], G l bal [F(1,11)=26.68, P<0.001], a d

Tab 3 Reac n s7 (n s7) eac s7 n l s7 c d

	G l bal		L cal	
	C s7 s7 e	I c s7 s7 e	C s7 s7 e	I c s7 s7 e
P n r ed s7 n l				
A n bl c e e	660	664	1164	1168
Fell e e	640	680	877	948
S n la r ed s7 n l				
A n bl c e e	920	952	1071	1122
Fell e e	749	920	809	912

Tab 2 E a s7 (%) eac s7 n l s7 c d

	G l bal		L cal	
	C s7 s7 e	I c s7 s7 e	C s7 s7 e	I c s7 s7 e
P n r ed s7 n l				
A n bl c e e	2.4	1.3	6.8	11.2
Fell e e	2.7	1.6	3.5	4.5
S n la r ed s7 n l				
A n bl c e e	2.6	4.4	4.3	3.5
Fell e e	0.0	3.3	0	2.3

C s7s7e c [F(1,11)=10.52, P<0.008]. S becs7 s7 d- ed s7e ... a s7.n la ... ed s7.n l (850 s7932.n s7). RTs7 ee l ... es7.n l s7e ed ... e a.n bl ... ce e a ... e ell ... ee (965 s7 817.n s7). F b s7es7 s7.n l, s7 s7s7 ... e, l bal s7 a e ee s7e a s7e e l cal s7 a e. RTs7 ee s7 e e, l bal a d l cal s7 a s7 eec s7s7e a e c s7s7e.

T ee ee e l a b l e e a c s7 ± G ... , G l b a l [F(1,11)=10.61, P<0.008], E e G l b a l [F(1,11)= 8.74, P<0.013], a d G ... , C s7s7e c [F(1,11)= 8.29, P<0.014]. T e e a c ... ± E e C s7s7e c s7 .n a, all s7, ± ca [F(1,11)=4.14, P<0.06]. T e, l bal RT a d a a r e s7.n es7 a l e ± ... n - a ± s7.n la ... ed s7.n l a d s7 ... e ± e a.n bl ... c a ± e ell ... ee. T e e e e c e e e c s7 s7 ... e ± s7.n la - a ... n ... ed s7.n l a d .n e ... ced ± e .n a l a e a.n bl ... c e e. P s7- c a a l s7s7s7 ed a e s7 s7s7 e l bal s7.n la ... ed s7.n l ees7 l e a s7e e .n ... ed s7.n l [F(1,11)=39.7, P<0.001], e e a s7 e s7 s7s7 e l cal s7.n l d d ... d e be ee e c d s7 (F<1).

I e c ... l c d ... s7 becs7 s7 ded s7 l e a d .n ee s7 e de ± ca ... ± e a s7 ± a s7, l es7.n all a ... s7e ed e a.n bl ... ce e a e ell ... ee [817 s7 651.n s7, (11)=2.71, P<0.02; 6.8% s7 1.7%, (11)=2.82, P<0.02].

A s7 s7 a l a c ± a.n bl ... ce s7 a s7 d s7 b ed e a d e a r e, e ± e a a l ed e c e l a be ee s7 a l a c ± a.n bl ... ce s7 a d e a s7 (a d RTs7) e a.n e e ± e c e ± s7 a l a c e ± .n a c e ± e a.n bl ... s7. T e a a l s7s7 d d s7 a s7, ± ca c e l a be ee s7 a l a c a d e e ± .n a c e ± e a.n bl ... s7 (P>0.25 ± all a a l s7s7), s7, s7, a e e e c ± e c e a l s7 a l e c e ±, l bal s7 c s7 ... be a a l e ± .n a c s7 c l d ... be acc ... ed ± s7.n l b e a a ... ± s7 a l a c .

Discussion

S becs7 s7 ded s7e ... l bal a l cal a, es7 e e e, es7.n l b e a.n bl ... c a d e ell ... ee. T s7e s7 l s7 a e c s7s7e e s7 l s7 ± e s7s7 d s7 e a l s7 becs7 [5, 14], d c a, a l bal RT a d a a r e. T e, l bal RT a d a a r e s7 ed ced e e l cal e l e n e s7 ee, ... ed b s7.n la ± s7 a s7 (s7.n l F, 2) c .n a e d e l cal e l e n e s7 ee, ... ed b ... n (s7.n l F, 1). T s7e ± d, s7 a e a r ee.n e e e s7 x [5] a d s7 ... e s7 a l a, ... b ... n ... c c s7 e a l e a, ... b s7.n la a d d .n a s7 e e c e ±, l bal s7 c s7. T e, l bal RT a d a a r e s7.n e ... ced ± e a.n bl ... ce e a ± e ell ... ee, .n a l beca s7e

± e . l, ed RTs7 e l cal s7.n l s7e ed e a.n bl ... ce e. M e e, ± b ... n - a d s7.n - la ... ed s7.n l, e RT d e e c e be ee e a.n bl ... c a d ell ... e s7 a s7 l a, e e l cal c d ... c .n l l e l cal e l e n e s7 ee d s7- la ed s7.n l a e s7 l, a ... e c ... l c d ... c a s7, l e l cal s7 a e s7 s7e ed. T e e ± e e l cal e c e ± c .n ... d s7.n l s7 .n a e d b a.n bl ... a, e e c, a s7, c d, e e c ± e a.n bl ... ce e.

I e s7, l, s7 s7s7 e l cal s7.n l s7 ed .n e e s7 e l cal e l e n e s7 ee, ... ed b ... n a b s7.n la . H ee, s7 s7 e ± s7 s7s7 es7.n l s7e ed e a.n bl ... ce e b ... e ell ... ee. R e s7 s7es7 eed s7 l cal s7 a s7 a s7 e d e d be s7 l e ± ... n a s7.n la - ... ed s7.n l, ... e d e e c e d d ... e a c s7, ± ca c e. T s7e s7 l s7 c l d ... be e e e d b e acc ± c ... e a c ... a e ... a l d e .n a d [2]. S c e e e e e c s7s7 a d e a c l cal a ... e s7.n la ... ed s7.n l, e e a s7 e a c l cal a ... a s7 a d a c e ... l a s7 e ... n ... ed s7.n l, e c ... e a c s7 l d be s7 ... e, a d s7e l e c ± a d d a l l cal a s7 l d be .n e d e c l, ± e ... c s7, ± l cal s7 a s7 s7.n la - a ... n ... ed s7.n l. T s7, acc d, ... e c c e ± c ... e a c ... a e ... a l d e .n a d, e c d, e e c ± e a.n bl ... ce e s7 l d be s7 ... e ± e l cal ... c s7, ± s7.n la - a ... n - ... ed s7.n l. H ee, ... s7 l s7 c a d c s7 ... ed c .

I s7 a s7 d e c l e l a e b e e l cal e ± - .n a c e ± s7.n la - a ... n ... ed s7.n l s7e ed e a.n bl ... ce e b a a ... ± s7 a a l ± e e c s7 e c .n d ced b e b a c ... d c s7s7. M x e s7 d s7 a e s7 ... a c s7 s7e s7 ± a.n bl ... ce s7 e a c s7 e e a .n l d e a a l e s7 a a l ± e e c a ell ... e s7 [12], d c a, a e a.n bl ... ce e s7 l s7s7e s7 e, s7 a a l ± e e c s7 a e ell ... ee. H e s7 e a l. [10] a s7 ± d e d e c e a e .n s7 e l e a s7 a a l ± e e c b a d ± d e c, e e a ... ± a ... x a d e d L a d l C s7 l e e a ± d e c, e e a ... ± a ... x a d e d L a d l C; s7, e c d, e e c ± e a.n bl ... ce e c a b e e - e e d b s7 l e s7e s7 ... s7 a a l ± e e c s7 a d e e e e .n e ± s7e s7 ... s7 a a l ± e - e c s7 e e a r e l e e s7 x a d e d b e l e s7 ... b a s7. Acc d, ... e a b e a a l s7s7, s7 a a l ± e e c s7e s7 l d ... d c e s7 ... e c d, e e c ± e a.n bl ... ce e. H ee, a l, ... e b a c ... d c s7s7 s7e d ... e c e s7 d ... d ced .n a l, s7 a a l ± e e c s7 (s7e [5] ± e s7 l s7 ± s7 a a l ± e e c a a l s7s7), s7 becs7 e ± .n a c e e l cal c d ... a s7 be e ± s7.n la - a ± ... n - ... ed s7.n l s7e ed e a.n bl ... ce e, c s7

... s7 e e edc ... e s7 a al e e c c e .
 T e s7 l s7 e c e k a e l e a s7 a l a e s7 a l e c e e a , l b a l s7 c e c l c a l e l e e s7 a e e d b e d e e d c b e s7 e c d , e e c a s7 a e c a n b l a . O e s7 k a s7 a e e c e e , l b a l s7 a e s7 e a e l c a l e l e e , s7 d n a e d b s7 n l a s7 a e a e s7 d n a e d b n [3, 5]. G e , e l c a l e l e e s7 e a c s7 s7 e l e c e d d a l c a l e l e e s7 a d d e e n e s7 c l e e l , l b a l l c a l , d n a e s7 e c e s7 , e e a c c a l a e s7 [4, 5]. G e a e l b a l s7 c e s7 n e s7 a l e e n a - a e s7 n l a - e d s7 n l , n a b e s7 e d a , a l e a s7 a c e a d e e e , e s7 a l e c e e e , l b a l s7 c e c l c a l e n s7 a e e d b e d e e d c b e s7 e n a n e e l c a l c e s7 , e n - e d s7 n l . I s7 s7 b l e a a s7 a l e , l b a l s7 c e , c a s7 b e e s7 s7 e d b e n e a e d b l s7 a a l - e e c c a e s7 [11, 15], d n a e s7 e e c e a l c e s7 , e e a c c a l s7 n l a d c n - e e s7 e c e s7 s7 e n e , a d d a l c a l e l e n e e d e e c a . T s7 e e c n a b e a c l a l s7 , e e a n b l c e e , s7 c e e s7 e s7 a l

c e a e c e e s7 e n e a n b l c e e a e n e s7 e s7 e l a , s7 a a l e e c e s7 [12]. H e e , s7 e , l b a l s7 a e s7 a l e c c l d b e e a e d b e b a c d c s7 s7 , e e e c e , l b a l s7 c e s7 a l e c e l c a l c e s7 , s7 e d c e d a d s7 l c a l s7 s7 e e a c l a e d . I e e s7 , e c d , e e c b s7 e e d e e a n b l c e e e c e e e n e n a a a l l e e c e e a c b e e e , l b a l a d l c a l e c e .
 P e s7 s7 d e s7 a e a b e d e c d , e e c a n b l a l a e a l b , a e a l d e n a d , a a e n s7 e l e a s7 a a l e e c . T e e s7 e e d , s7 d c a e a d e e c a e l c a l s7 a e s7 e a c c a l a e s7 c l d b e s7 e e e l b a l s7 c e e e a c c a l s7 n l s7 s7 a l e a e s7 a n b , s7 . T e s7 l s7 c a b e e l a e d b e l a e a l b , a e a l d e n a d , e s7 a a l e e c c c e s7 , b a e c s7 s7 e a s7 a l a e s7 a l e c e e a , l b a l s7 c e c b e s7 e n a n e e l c a l c e s7 , a n b l a .
 Ac w , P u n n a T s7 k a s7 s7 e d b e N a a l N a a l S c e c e F d a e C a (P e c 30225026) a d b e M s7 e S c e c e a d T e c l , e C a (P e c 2002CCA01000) .

References

1. Fl n MC, We n FW, Ka e n a D (1963) V s7 a l e s7 l a d c e a c . J O n S c A n 53:1026 1032
2. Fl n MC (1991) C e a c a d e c d , e e c . P b l O n 3:237 257
3. Ha S, H n e s7 GW (1999) I e - a c s7 b e e e c e a l , a a b a s7 e d G e s7 a l l a s7 a d s7 e b a s7 e d e a c c a l c e s7 , . P e c e R s7 c s7 6:1287 1298
4. Ha S, H n e s7 GW (2002) S e - n e a a d s7 e l e c c b e l c a l c e s7 , e a c c a l a a l - s7 s7 . Q J E R s7 c l S e c A 55:5-21
5. Ha S, H n e s7 GW, C e L (1999) P a a l l e l a d c n e e c e s7 s7 e a c c a l a a l s7 s7 : P e c e a l e , a d e c d , e c l s7 e . J . E R s7 c l H n P e c e P e e n 25:1411 1432
6. Ha S, H n e s7 GW, C e L (1999) U e n c e c e d e s7 a d c l a s7 c a l G e s7 a l c l e s7 e e c e a l , . P e c e R s7 c s7 6:661 674
7. Ha S, S , Y, D , Y, e a l (2001) N e a l s7 b s7 a e s7 s7 a l e c e a l , n a s7 . R s7 c s7 1 , 38:926 935
8. Ha S, H e X, Y d E W, e a l (2001) A e a l s7 e l e c e c e s7 , e e a c c a l a e s7 : E R P s7 d . B R s7 c l 56:113 130
9. H e s7 R F, J a c b s7 R J (1979) A e l n - a e e e a c a d c - e a c a c s7 e a n b l e s7 s7 a l e i d . V s7 R e s7 19:1403 1408
10. H e s7 R F, D a k S C, K a n N (2000) T e e a l ' c d , e e c : s7 s7 s7 1 , ? V s7 R e s7 40:365 370
11. I R B, R b e s7 L C (1998) T s7 d e s7 e e c e . MIT P e s7 , C a n - b d e , M a s7
12. K e s7 L, K e D C, O' K e e e L P, e a l (1998) N e a l c e l a e s7 e a n b l - a e s7 a l c e e e n a c a l e n a e s7 e e n e a l s7 a b s7 n s7 a d a s7 n e . a . J N e s7 c 18:6411 6424
13. L e D M, K l e S A (1985) V e e a c , c d , a d a n b l a . V s7 R e s7 25:979 991
14. N a D (1977) F e s7 b e e e e s7 : e e c e c e e l b a l e a e s7 s7 a l e c e . C , R s7 c l 19:353 383
15. S l n a G L, S l l a M A, G s7 K, e a l (1986) T e l e s7 a a l e e c c a e s7 e e c e e l c a l a d l b a l s7 c e . P e c e . 15:259 279