Legibility Variations of Chinese Characters and Implications for Visual Acuity Measurement in Chinese Reading Population

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Purpose. W C c a a b f c a ac a d a f a a c . C - , b f C c a ac c d a ca , a d a ab ff c a f d a a f c a f C ad a . T f d a a c a c ca d f C c a ac b .

Methods. T a b a a C c a ac- , a ac f f C c a ac f a a c a d f S a d d a - d C b . T a b b a d ca d f c d d f La d C, S E, a d f C c a ac , d , a d a a c 26 a - d C ad .

Results. T ac f C c a ac c a d ad c , a a a a d b c d f a ac ba d d a f . T ac ca d f c f c f C c a ac a d S E ad a a d d ff d b a ca f , d d- a a c . T f c f La d C a ca .

Conclusions. T d d ca a a ac a - C ad c ca d b a a c - f C c a ac , b fac a S E, c c a a a da d f ac a C a, a d C c a ac d a d d c ca d f c a d ca a a a d a f f c a C ad S E ac . (*Invest Ophthalmol Vis Sci.* 2007;48:2383 2390) DOI: 10.1167/ .06-1195

V a ac f d b c ca ac c a d ba c a c . T a - a c a d, fac a a ac a d f a d b d ff . T d fac f a a c c a a ca c a a.[1] F , a ac a d d a a a f a a f a a d d c b d b d a (a f , MAR) a ca b - d. I a a[2] a d U.S.[1] a da d c d - a d f - a La d C a a a ac . B a da d a a a f C a d a b d a d a d f a , c f f a , a f a ac . I C a, a da d S E,[3] d f f . F f fac , a ac a d a a a da d a d d b f f b ' a a d c a bac d.

H , a a c ca c a- b a a a d a a c c .[4] E fac a a c c d, a f a c ca b a d b d a a d a a f f a a a a b d a d a c d , c a a c , c a , a d d ab a . T f , f c a d a f c a d a , a ab a , b a ca , a d d - ab b , a ac d a a a ff c- a a , a ca f - a d ac d c a c d . F a a ac a b f c a a , d b c a d b ' a a . F a b- , a a a d b d ad f b ' a a a .

B ca f a c f ad f c a , c a a b c d a a f c ca a a ff c a a d d. H , a c a a a , a d a c d a ca b c d d. T f , a ac f f ac a d f f c a a a a b a c a .[1] B a a a d U.S. a da d a a a a , c a , d b a La d C . ISO 8597 (I a- a O a a f S a da d a)[2] a a a f a La d C f d ff a 0.05 . I U.S. a da d, a d d ff c 5%. If a a a f a La d C, a c fac d b d d ca . I c -ba d a a , a a R a a ab , a a b f ac- d La d C ac a d f c a d ac a a ac . S a a.[5] d ac 214 a f ac b La d C a d ca E CDHKNORSVZ a d f d a a c a d (P a $r = 0.90$). W c a b a a d a - a ca b ab d, a f a , MAR (a f) MAR, ca b d f f c a a , f

F [1]S a K Lab a f C N c c a d L a , B N a U , B , C a; [2]I f N c c , C Acad f Sc c , S a a , C a; [3]EENT H a , F da U , S a a , C a; a d [4]Sc f O , U f A aba a a B a , B a , A a- ba a.

S d b B N a U a d C Acad f Sc c .

S b d f b ca Oc b 5, 2006; d D c b 31, 2006 a d Ja a 17, 2007; acc d Ma c 16, 2007.

D c : **J.-Y. Zhang**, N ; **T. Zhang**, N ; **F. Xue**, N ; **L. Liu**, N ; **C. Yu**, N

*Eac f f a c d a : C Y , S a K Lab a f C N c c a d L a , B N - a U , B , C a; c @b . d .c .

L L , Sc f O , U f A aba a a B a , B a , AL; 7788@ ab. d .

TABLE 1. R a L b f S a L a d C C a ac

Sloan		CC1		CC2		CC3		CC4		CC5		CC6	
R	0.38	文	0.32	只	0.39	条	0.35	张	0.16	验	0.24	路	0.44
O	0.40	天	0.39	任	0.39	非	0.36	资	0.37	领	0.38	题	0.46
S	0.51	力	0.47	区	0.44	各	0.37	很	0.38	群	0.57	德	0.52
K	0.53	么	0.51	风	0.51	医	0.53	售	0.49	势	0.57	赛	0.54
D	0.54	个	0.52	日	0.58	抓	0.54	建	0.53	笔	0.60	整	0.58
C	0.57	之	0.57	以	0.61	取	0.56	做	0.60	想	0.60	需	0.6
N	0.57	十	0.57	世	0.62	申	0.65	深	0.63	堂	0.62	感	0.62
H	0.75	少	0.60	无	0.64	名	0.68	益	0.66	数	0.62	就	0.66
Z	0.82	山	0.75	州	0.73	多	0.78	事	0.68	续	0.64	增	0.69
V	0.90	人	0.78	占	0.81	好	0.86	学	0.92	率	0.66	解	0.75

I f a c , c ca d ca d, f a S a a C c a ac b .

Apparatus

T a d b a Ma Lab-ba d (T Ma W , Na c , MA) W V a (N c I , Oa a d, CA) a d d a 21- . c (2048 × 1536 , 0.189 × 0.189 / , 75-H f a a). T a a d - a c f a 89 a d 0.02 cd/ ². A a- a c , b ac a a - a c bac d. Ob d d a b c a a d . A ab a c ad c b a d a a c c d a c .

Observers and Procedures

I a f d , d a f b f C c a ac a d a f ff c f ca d f c C c a ac b , d ff f b a d d ff c d d.

Chinese Character Legibility

S (a a , 22.8 a) a C a a c c d- - a d a b . A b ad a c d ca a d a a 7 a f a ad a d E . E c ZJ, a c a , a c ca b - a a d a a f f d . Eac b d f ac b a a d c c a a S E b a d a d d a c f 5 . M b c a d c c . T a a b c c d ac a −0.114 ± 0.049 MAR.

S a a d C CC1 CC6 d. A d f c a a d a ac f a . A a d a c f c c d d a . T b ' a a f a 10- a - (0 9). A d f dbac a c c . S f a a d f ac . T - a a a c a d b c a d a c c a ca c (40 × 40 f S a a d 50 × 50 f C c a ac). L c f a c c a a c c a a f d - a (10 × 5 a). O d f c d f 42 (×), c acc d a a d d ab f ac b a d ca c d a da . F b f d 10 d f , a d f d d .

T c a f c c da a f ac a d a W b f c : $P=1-(1-\gamma)e^{-(x/th)^{\beta}}$, P a - c a c c , γ a a (0.1 a 10-AFC a), x a a c , β a f c c f c , a d th a d a a 66.9% c c . I f a c ac f f f d a c , a d MAR f f f ac , f c C c a ac , MAR a a -d d f a .

The Effects of Optical Defocus on Chinese Character Legibility

T - b (a a , 25.9 a) a c c d- - a d a b . La d C a d S E a f a a d f C , d , a d a a c d. Eac c a d (F . 4a). T C ac d f a CC1, CC3, a d CC6 F 1. T a d a c b (Tab 1). T a 125 × 125 , a d a 25 × 25 . T a a d d a a a d a c ac f a c . T c d f f a d - c d f a . I ac , a d d d a d f a - a d. T a a b a a d f . T a d a c f c . T a a b ac c a a a ac d f , c ad a a d - f d f a d a a a d f b d .

A b f ac d a S E b a d a d d a c f 5 . T a b c c d a ac a −0.126 ± 0.054 MAR. A b d d a d a f a d a c f 6 , b c c a a f a . Ac a d d f c d : b c c d a add a 0-, +0.5-, +1.0-, a d +2.0-D ca a a d d . T d f d ac c d a a a d d. I f a b f a d c a a a 6 d add f a +1.0- +2.0-D , d a c

a a d. T
fac a
T b '
. T
d. T
ad a f
a a
d

d c d b a
f
a f
f
c d
f
a c d d acc
a c d d
W f
a c ad d

RESULTS

Legibility of C

F 2a
W b
a
a d f

a '

c

a
ac

a

a d . I ,
ad a
, f da a fa
c f c . T f ,
acc a a d c
a C c a ac .

Re

R ac a
d Tab 1. (R a b d-
b a a f d
d f c c c -
f a b . N a a
c c. T a Tab
c 10
a b a d a .
a d a b a 10 S a
a 26 ca d ,
a a b .[18]) T χ^2 d
f ac a
($P < 0.0005$), d ca a
a b . I c a ,
f a b da a (Tab 1) a d a f
.[19] ca d ff ($F_{9,9} = 1.228$, $P =$
d ca a f acc ac . T a -
f a b CC1 CC5 da a
ca d ff f a f S a da a ($F_{9,9} =$
, $P = 0.427$). CC6 ad a ca a a a c
d d S a ($F_{9,9} = 7.996$, $P = 0.037$). T f ,
ac C c a ac c a d b
d b c a ac , ca f a b
a a a a f
S a b d d .[19] T f , CC
a acc ab f a b a d f-
f a a c . T a a
c a a f E c d a d a c a b a
a acc ab a c f a b .
T d f a f d a
c c f C c a ac c . I a -
c d ca d f c (F . 4),
d a a b f
ac d a a f a
. T ca b a d
a d c a ab .

Further Analysis of Acuity Differenc
Sloan Letters and Chinese Character

I F 3, ac d ff c b
a d S a a d
a d. S c d ff c a b a d
a a C c a ac
. T d a , a da a f S
a a d d c c a
a d 85% a d c f
c c f a
ca ac , c c
d d c f ab
b .[20] A
d ,
V, H, a d Z (91%, 88%, a d 76% c c).
T c a c , ca ba , a d ba
. T c -
f d c (F . 5a). c , -
, c a c f V a ac d b a b ad , a d
ca ba f H ac d b a ba f
工. A ac d d c a a
c f , d c d c f (F .
5b). N , a ba f 工 c d b c f d
f 乙. T b ad f 入 a a b a f 大.
I d d, 工 a c f d 乙 12% f , a d
入 a c f d 大 11% f (F . 5b). A
a c c , c c a f 入,

. I c a , C c a ac a c - a (-b d) c d f c a . B ca c a a a c d c f a a b c , d a a a a f R a . A a c c , a d ac C c a ac a c d c ab . F a G a c f , C c a ac a a d a a R a a ab , b ca C c a ac ff a a a , a d d a a f a a- .[21] N - - d a f a d b a d c a d a f f a . I d d, P a .[22] f d a a f c c f c C c a ac a d f f c c f c a E . I d , , CC1 a a a - d b a S a (F . 2b), a a - d b f d c d b f c c d ff c . T ac d ff c b ca a ca ca a a d (F . 3b). T a ad a a f E C - c a ac ca b a d b a f ac a . Ac a a c b c a f c d f c d ca ba d ba f a f , b ca f a a b - ca a a d c d b c a c . T - a b c a a a a f a ca d ff c b . I a a a ca d , d a d a d a c a a ac d d b a f - d c , c ca d ba c a ac c f -d a a , c d acc f f ad b a b c a -ac S a a d C c a ac . A C c a ac a a a d f c- a a a E d. C ca b ad c a fa a E .[23] R c f C c a ac f a f c a c f - E d (a a f E d).[22] H , ad a a f C c a ac E d d d a ac . O d a CC1 a 37.2% b a S a . M a , S d a .[24] c a d ac f S a a d ca E d ( ) f f fac a d f d a ca d 4.5% 7% b a S a . T da a d ca a CC1 a a 33% b a ca E d . W c a a a ac , ba f ca c f , a , a c a ac a d, d ac . Fa a a f a a ff c .

Deriving a Visual Function Measurement from Snellen E Acuity

T d ff c b a a 60 C c a ac (人, 3.77 a c) a d d f c (驗, 6.90 a c) a 0.263 . T b a ab f c a ac- a C b a . Ca d a CC f d a b a d ac a f c a a f C ad ? B f ca c a a , b f c a ac f d ff c c a c d c a . If a c a , ac f a b d a d a f c- a a f a c d , c a ac a d a d d a f ac . T a a a f S E, CC1, CC3, a d CC6 F 4b ab a ac a a ' S E ac f a ' f a c C c a ac f d ff a a c . T c CC b a d a d f ad C ? O d b b f a cc f da C . S a .[25] d d f 2570 C c a- ac d f c a a c b B . T d b f b a d f 1 24 a d c d b d a Ga a a a 9.10 ± 0.09 . O CC3 ( ) c a . T ac f CC3 0.210 a a a f S E (F . 4b), c c a ca fac f 1.622. T f , f a ad d d b ad 100 a a b a d 20/20 , C c a ac a b a a 1.622 × 100 × a (5 a c) = 0.236 , 23.6 c a . B ca d ' d d b a S E c a , 1.622 fac c - a f ac d ff c b S E a d a a C c a ac .

I a C c a ac d d d c a ac , c a a da d a - a d C a a d S a . Ma d c a ac a f a c d ad a c a ac . F a c , d c a ac 无 (, d) CC2 d b 無 a a ad a c a ac . T d b f b f a d a ac a b a f ad a C c a ac , a d f Ka Ja - a , b ca f a ad a C c a ac- .

F a , a a a a a- b S E a d C c a ac F 4b a b a d b d c ca d f - c . W d (d c b) a b d d a f ac , b d ff c a . W a c a c ca a a a d a a cc f ac .

Conclusions

M a f a ac f S a a d C c a ac f d ff b f a d a c ad a ac . T c a f ac a a c , , a fa a a ac a d - d b d c a f a d a . S a ad ca a ac a f C c a ac , ad c a- ab a a c . T d ff c , , c d a - a b a d b d d ff c b . W ca d f c a d c d, ac f C c a ac c a d a a a S E . S c a a d a f c a a f S E ac a - a C ad .

Appendix

Selection of Chinese Optotypes

F , 500 f d C c a ac (CC) c d f a f c a c a ac -f c ab ,[26] c a c d ba d a c c f 138 - CC . S f CC c d ba d b f (. ., 2 4, 5 6, 8 9, 11 12, 13 15, a d 16 18). T d c c a ac a a a ab - b , a c a a f ca a a c a ac- ac a c d c d. T 50 × 50 b a f ac c a ac a c d d a a a 50 × 50-d ac , c d a $x_1, x_2, x_3, \ldots, x_{2500}$). T c - d a 0 (a b ac) 1 (a). T

E c d a d a c b i a d j c a ac
ac a $d_{ij}=[\sum_{k=1}^{2500}(x_{ik}-x_{jk})^2]^{1/2}$. A a - E c d a
d a c a f a c a ac
ac ca c a d. S a d [15 17] a
a E c d a d a c c a d c d a
b E . F ac CC , 12 14 c a -
ac d a E c d a d a c f ac
c d. T c d c d d c a ac a
ca a d ff . Add a c d-
a f c a a d a a c a f
d c d b f c a ac ac 10. T
a f C a F 1a
(CC1 CC6).

Calculation of Optotype Stroke Frequency

A b f a b d a d
f c d c f ,
a d a f a a c b ca a b
f a a a a f , a d
a d a d a f d . F
a , a c a ac □ c a f a
, a a
ca d c . C a ac 三 ( ) a d 川 ( ) a
ac , b d ca
a d c 1.5 f a f □. A b c
a f a a c f f -
c .[27] I a a d d a a b f
c d b a c d . B ca
a C c a ac a ba a c d b f
c a (f a , c d a d d c a -
ac CC4 F . 1a), a d b ca C c a ac
a d a b (a c a ac f
CC3), a ca d d a d ca c a
f c f . A F 1b,
ac a c d - d c
c b a : a a d
a , ca f a d a , a d b a
45 a d 135 c a f . A a f
c d a b a d f ac c , a d a -
f c a a a f c f
. T a a f c f S a
a 2.0 / , a a a b a d
a c (1.6 /).[27] T a a f -
c f C c a ac c a d
ca f 2.2 5.5 / .
A a f a a c f a
c c .[22,28] P c c a -
a a a f d a d d d a a f
d -a d- d f a a , d d d b
a a. W ca c a d c c f a -
d d a d f d c a d
f c (r = 0.956). B ca f c
f