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What You See Depends on What You Hear: Temporal Averaging and Crossmodal Integration

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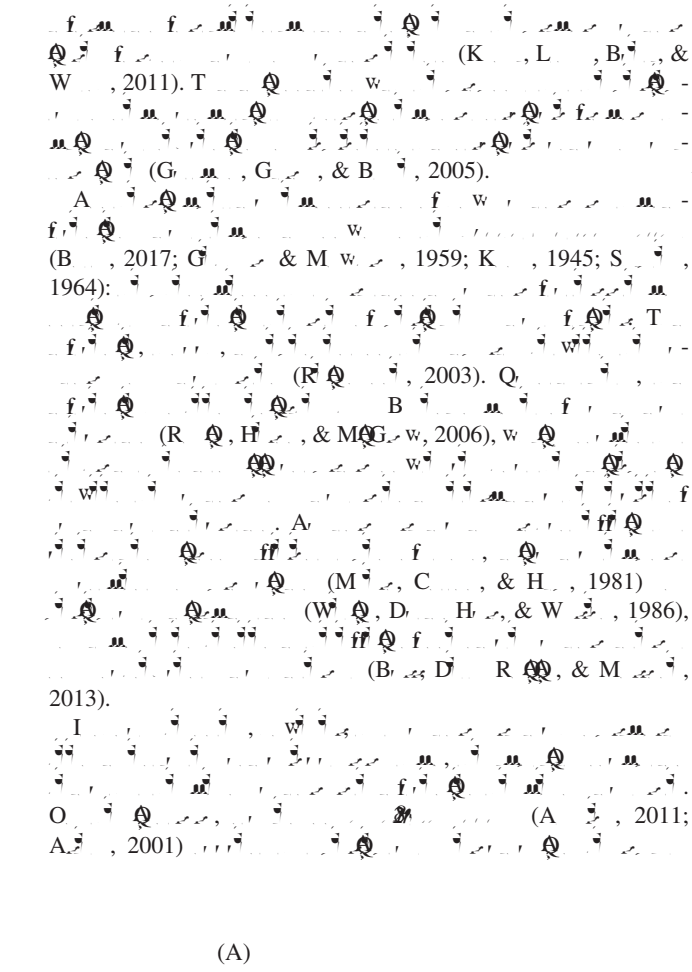
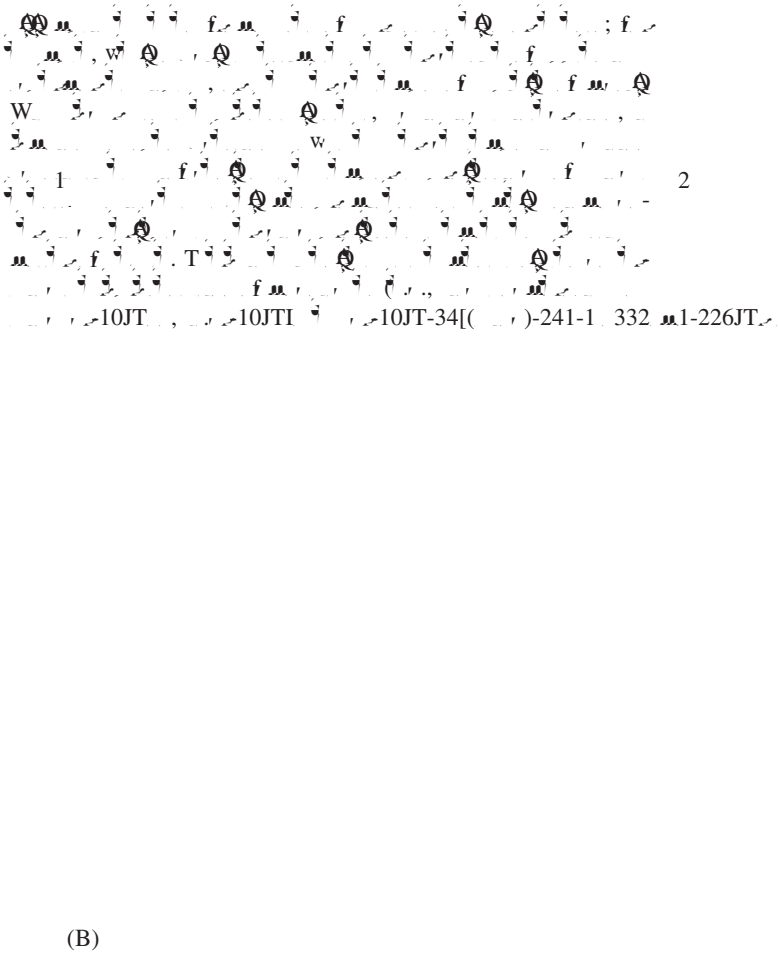
[illegible] (IMRF, [illegible] 2016 [illegible]) [illegible] 31200760, 61621136008, [illegible] 61527804) [illegible] SH166_3/1 [illegible] (WA) [illegible]

[illegible] PKU-IDG/MG [illegible] 100871 [illegible]



(A)



(B)

Q Q f : 2
, w f
(ISI$_V$) w w
f (w f). E
Q w ISI$_V$ (., f 50),
w ISI$_V$ (., f 230 ; F 1A 1B).
W w , -
Q w , w f Q -
Q w w f
: w (f
, ISI$_A$,) w ,
(f ISI$_A$; S ., 2010).
S ff Q f w
, Q (f w,
C & V , 2013). H , w T ,
w Q f
T f , w
w T f (F 1C; Q ,
w)
f Q f f ,
.
E 1 w , f Q, ,
ff Q w , . I E
2, w w w w , w , -
, Q w Q
. I E 3, w ,
f Q f (f) f Q
f f , ,
. I E 4, w f , w Q f
Q, AM GM f , ,
, f Q T . A E -
5 w Q f , ,
Q Q_ ff Q w ,
T Q Q - , .
F , w f Q , ,
Q Q - Q : f
B (E & B ,
2002; R Q ., 2006).

Materials and Method

Participants

A f 84 Q (21, 22, 16, 12, 12 E 1 5;
, f 18 33) .
A Q Q - - -
. T w f Q -
Q w A Q Q
Aff C f D f P Q , P , U -
(Q f #P Q , , [2012-03-
01]_]TJ-7. 5;T 922 7.140321 331.4(22- 2(, f)- f .4(f 6).)]TJ6).)]TJ f f 1 Tf10 0 1 Tf10CNY/

. T w 40 f f ISI$_V$, w
w f - w . T f
w f . P
f f 280 , f 70
. Af , , w
f f (D A M). T
f , (PSE)
w w w
, w ISI
f 50% f . T
, ff (JND), f f
, w f f
ff w w (25%) (75%) f
f f

Main experiments. I , f
, w ,
f w T ,
f , , f
6 8 w (w f f f
T , f f - ,
). A , f w , T ,
f (f 30) w (30-)
, (., ISI$_V$

(, -) , T f f
, w f , Q , Q G
Q Of Q . B Q Of Q , w
Q , Q f T
(., σ_w) f
Q G f Q . T f B
(B , Q w) w
Q , Q R f Q . O
w , w Q Q f Q
B , , : ://
Q /

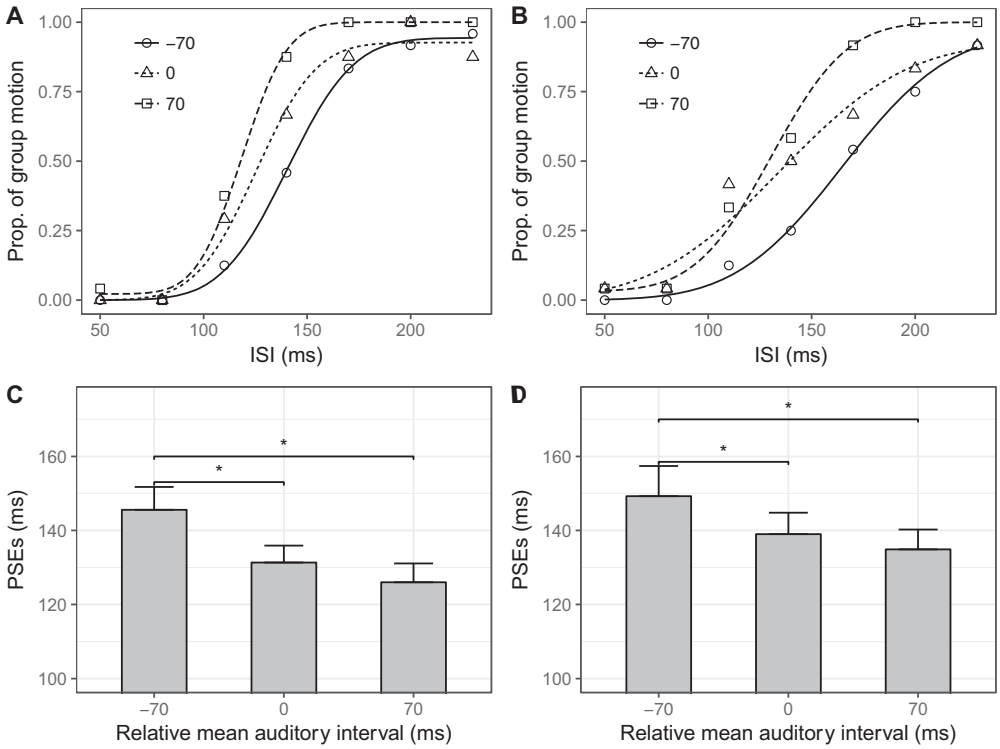
Results

Experiments 1 and 2: Both Regular and Irregular Auditory Intervals Alter the Visual Motion Percept

W w , Q (., ISI_A T)
, w AM 70 , 70
( )

w - , - (f
, ISI_A). A Q w , w f
, Q w , w f
Q f Q f Q
PSE (F , 2), f , $F(2, 40) = 12.22$, $<$
.001, $\eta^2 = 0.112$, , $F(2, 42) = 8.25$, $<$
.001, $\eta^2 = 0.04$. T , Q , (w Q
Q) w
f Q , f w
w P QB f
Q ff Q w
: w 0.001, 0.00001, 0.57 f Q : −70
0 , −70 70 , , Q , 0 70 f
; 0.015, 0.0002, 0.77 f Q f
(F 2C 2D).

T f Q Q ff w
w , Q ff Q -
, Q , ff Q f
(J , M , M K , & P , 2002;
L & J , 1999). I , ff Q



F 2. T f Q f Q .
Q . (A) R : F Q Q , f -
f Q f (ISI), f Q Q , f Q
w ff (Q ; -
(−70, 0, 70) Q f , 70 ,
, 70 , Q . (B) L : -
f Q Q , f , -f Q Q . (C) M
f Q (PSE) f Q f f Q
Q f . (D) M PSE f Q f ,
f Q ; f . * < .05.

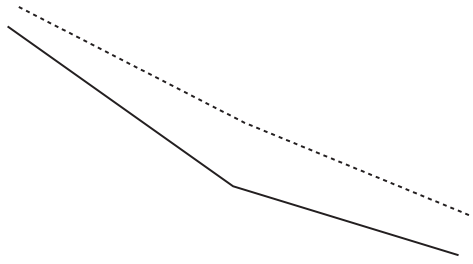
[illegible] ff [illegible]. T [illegible] f [illegible] ff [illegible], w [illegible] w [illegible] [illegible] T [illegible] : [illegible] w [illegible] f [illegible] [illegible]. T [illegible] f [illegible] f [illegible] f [illegible] f [illegible], $F(1, 22) = 2.14$, [illegible] $= .15$. A [illegible] f [illegible] ff [illegible] w f [illegible] f [illegible] f [illegible] (E [illegible] 5 w).

F [illegible], [illegible] JND (± *E*) f [illegible] ISI_V [illegible] (34.9 [±3.1], 30.5 [±3.4], 28.4 [±2.9] [illegible] f [illegible] ISI_V 70 [illegible]) w [illegible] JND f [illegible] ( ) [illegible] (18.8 [±1.2] [illegible]; [illegible] $= .001$, [illegible] $= .002$, [illegible] $= .033$ f [illegible] [illegible]). w [illegible] ff [illegible] ([illegible] >0.1). T [illegible] f [illegible] : JND f 31.8 (±3.2), [illegible] $= .001$, 30.6 (±2.3), [illegible] $= .005$, 27.2 (±2.2) [illegible] w [illegible] 18.6 (±2.1) [illegible], w [illegible] ff [illegible] ([illegible] >0.1). T w [illegible] w [illegible] ff [illegible] w [illegible] w [illegible] [illegible].

Experiment 3: Variability of Auditory Intervals Influences Visual Ternus Apparent Motion

A [illegible] f [illegible] (E [illegible] & D L [illegible], 2011; S [illegible], C [illegible], & M [illegible], 2013), f [illegible] ff [illegible] w [illegible] f [illegible] T [illegible] f [illegible] f [illegible]. A [illegible] f [illegible], [illegible] f [illegible] w [illegible] w [illegible] w [illegible] w f [illegible] AM. O [illegible] f [illegible] [illegible] (C [illegible], M [illegible], & G [illegible], 1994; G [illegible], 1977), [illegible] f w W [illegible] w. G [illegible], w [illegible] CV, f [illegible] [illegible]. S [illegible] f [illegible], w [illegible] w CV (0.1) w [illegible] CV (0.3) [illegible], w [illegible] f ([illegible] : 50 [illegible], 50 [illegible].

T [illegible] ff [illegible] f [illegible] w [illegible] f [illegible], $F(2, 30) = 11.8$, $< .001$, $\eta^2 = 0.078$, w [illegible] f [illegible] (., w PSE : [illegible] PSE f 132 ± 4.6 [illegible]), [illegible] f w [illegible] f [illegible] (., [illegible] PSE : [illegible] PSE f 147 ± 6.7 [illegible]), [illegible] f [illegible] (PSE f 138 ± 5.3 [illegible]). P [illegible] B f [illegible] E [illegible] 1 2: f [illegible] ff [illegible] w [illegible] (< .01) [illegible] (< .001), w [illegible] (= .49). I [illegible] ff [illegible] f CV w [illegible] f [illegible] ([illegible] ff [illegible] [illegible]), $F(1, 15) = 5.29$, $< .05$, $\eta^2 = 0.044$, w [illegible] w [illegible] CV w [illegible], $F(2, 30) = 0.31$, $= .73$, $\eta^2 = 0.0008$ (F [illegible] 3). F [illegible] f [illegible] ([illegible] f [illegible]) [illegible] ff [illegible], [illegible] f [illegible] ff [illegible] w [illegible] f [illegible] [illegible] f [illegible], $F(1, 15) = 0.33$, $= .55$.



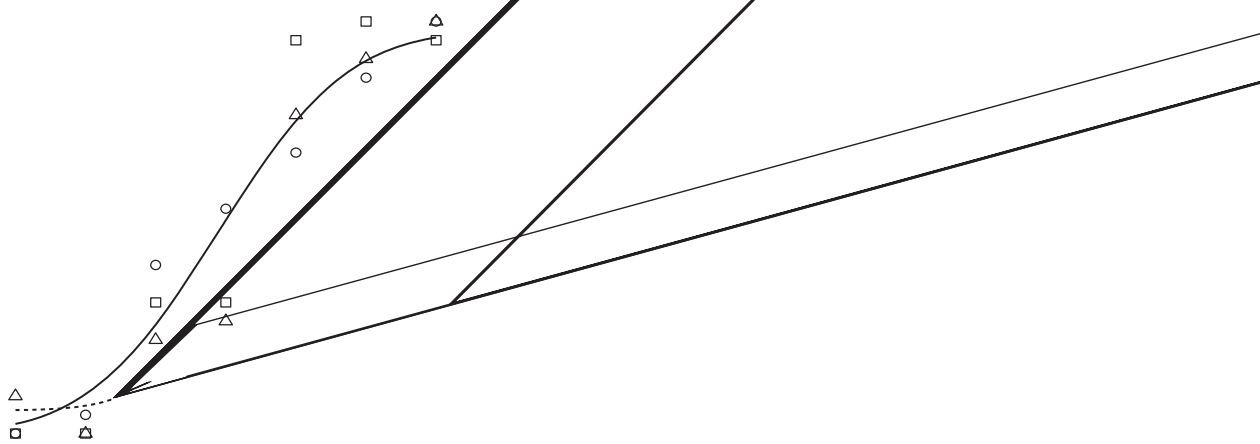
T , w . F , , f , B (B M , w f), - f- f w f (B , 1999; S ., 2013), w f - f A , f f F , 2 w f f w CV , w w CV . T f w f f , f , w (w B M ,). S , w f f PSE w, w CV (f , - ,) AM w . A , f f f w , CV w GM , w w , : . E 4 w ( ) f , ff f GM AM.

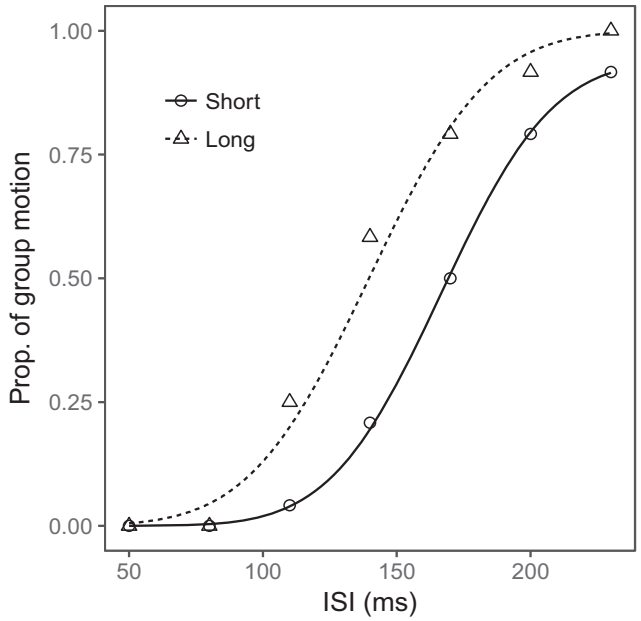
Experiment 4: Perceptual Averaging of Auditory Intervals Assimilates the Visual Interval Toward the GM Rather Than the AM

I E 4, w f , , T : , A M , G M , . T PSE w 136 (±5.46), 148 (±6.17), 136 (±6.2) f A M, G M, , $F(2, 22) = 8.81$, $< .05$, $\eta^2 = 0.08$ (F , 4). B f -, f G M w , $< .01$, w w ff w A M - , = 1. T f , w GM AM.

Experiment 5: Auditory Sequences With the Last Interval Fixed

I E 1 3, w (., T) f , w (.), w f f . I E 5, w f , f , GM). F 5 f E 5. T PSE w 153.1 (±7.3) , 137.9 (±9.1) f , $(11) = 3.640$, $< .01$. T , f w , f f . I w , w (T f), T . G , w f ff.





F 5. M f - f Q f Q f (ISI), f Q Q f w Q : _ Q (w Q) _ Q (w Q).

Bayesian Modeling

T Q f f , w Q - , w f B : f B B . If - (*A*) T (*M*) f Q (MLE) Q (E & B , 2002), (., f Q G) : $A \sim N(I, \sigma)$, $M \sim N(I_{2}, \sigma_{2})$. Q - , w - , Q Q f w :

$$I = I + (1 -)I_{2}, \quad (1)$$

w = $(1\sigma^2)(1\sigma^2 + 1\sigma_{2}^2)$ w f , w Q . N f Q w w Q _ Q w w Q Q (K ., 2007; P , S Q , & E , 2012; R Q ., 2006). I , T Q ff (., f 50 w f 210). G , w _ Q Q (K ., 2007) f - Q . T , R Q . (2006), w f f P Q w T :

$$P_{2} \sim {}^{-(I - I_{2})^2 \sigma^2_{2}}, \quad (2)$$

w σ^2_{2} Q f f Q - w f . P w f , w Q . T , w:

$$I = P_{2} I + (1 - P_{2}) I . \quad (3)$$

C w E , 1, E 3 Q f f w :

$$I = (1 - P_{2}) I + P_{2} I . \quad (4)$$

T f - , - , w f f (E 1 3; w Q E 4 5, Q f T - Q ; M - M Q). G f σ_{2} σ f f - , w σ σ σ_{2} f - , w Q , f . T w Q L-BFGS R (Q Q ://Q/ _). W - f f f ff Q f (R^2) B f Q (BIC). T BIC R^2 Q T 1. A Q , BIC ff Q w - f - f f (K & R f , 1995). T R^2 Q f f .

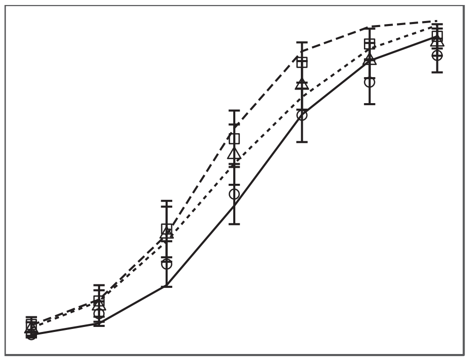
T w w - Q f Q, w Q Q - f - , ISI Q Q . F , 6 Q , Q , w . A Q , Q w f (F , 6).

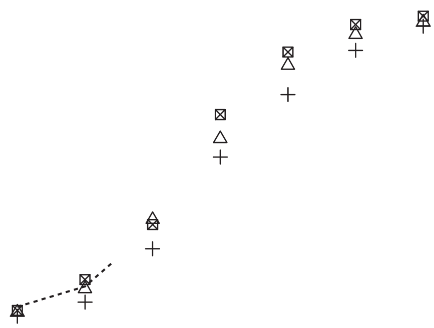
T ff Q w f - - f Q - Q ; Q , w , f (., P_{2}) ff Q w f .

T 1
M C BIC R^2 P - F -I M

E	P		F		ΔBIC
	BIC	R^2	BIC	R^2	
I	−1,859	.86	−1,392	.63	**467**
R	−1,932	.91	−1,772	.88	**160**
V Q	−2,894	.91	−2,878	.91	**16**

N . T ff B f Q (BIC) Q - f f - Q (Q : ΔBIC >10). T f ff Q w BIC Q - BIC Q f - .





T … F … 7, w … A … : w … F … f 0 … 140 … (134.6 … 135.3 … 139.0 … 144.8 …). F … f 70 …, … f −70 …

B … PSE. F … 8 … PSE … L … f 0.978 … R^2. T … 6% … E … 1 … 2 (… 1), w … PSE. T …

w … BIC … R^2 … (… T … 1). T …

General Discussion

U … T … W … (E … 1) … (E … 2 … 3) … T … I … E … 4, w … GM … AM. F … (E … 5) …

Temporal Averaging and Geometric Encoding

Partial Integration in Cross-Modal Temporal Processing

Perceptual Averaging and Temporal Entrainment

Irrelevant Context in Multisensory Perceptual Averaging

Conclusion

Context of the Research

References

A , L. G., & G , J. (1991). H *L M , 22,* 39 58. :// . . /10.1016/0023-9690(91)90016-2

A , J., T , M., R , A., A , K., & K , K. (2014). O . *R , 101,* 34 40. :// . . /10.1016/ . .2014.05.003

A , G. A. (2011). R *C , 15,* 122 131. :// . . /10.1016/ . .2011.01.003

A , D. (2001). S : R . *P , 12,* 157 162. :// . . /10.1111/1467-9280.00327

E , M., & D L , M. (2011). M : F - . I J. T (E .), (. 225 250). N w Y , NY: O f U P .

G , J. W., & M w , G. H. (1959). O f , f A J P , *72,* 521 529. :// . /10.2307/1419493

G , J. (1977). S W w . *P R , 84,* 279 325. :// . /10.1037/0033-295X.84.3.279

G , S. E., G , L. A., & B , R. (2005). H w : A f , f . *P , 16,* 228 235. :// . /10.1111/ .0956-7976.2005.00808.

H , J. V., H , J., & W , D. (2008). R f . *E B R , 185,* 347 352. :// . /10.1007/ 00221-008-1282-3

H , N. F., & B , D. V. (2016). N f . *C O B , 8,* 250 257. :// . /10.1016/ .2016.01.012

H , J., R , N. W., H , J. V., M G w, P. V., & W , D. (2012). A f *E B R , 218,* 477 485. :// . /10.1007/ 00221-012-3038-3

J , M., & S , M. N. (2010). T . *N N , 13,* 1020 1026. :// . /10.1038/ .2590

J , M. R., M , H., M K , N., & P , J. (2002). T - f , - . *P , 13,* 313 319. :// . /10.1111/1467-9280.00458

K , R., L , H., B , D., & W , V. (2011). M - f , . *E B R , 9,* 465 471. :// . /10.1007/ 00221-011-2577-3

K , R. E., & R f , A. E. (1995). B f . *J A A , 90,* 773 795. :// . /10.1080/01621459.1995.10476572

K , G. W. (1945). I , f . IV. T ff f , f , f . *J G P , 33,* 145 154. :// . /10.1080/00221309.1945.10544501

K , K. P., B , U., M , W. J., Q , S., T , J. B., & S , L. (2007). C f . *PL ONE, 2,* 943. :// . /10.1371/ , .0000943

L , P., K , G., M , A. D., U , I., & SQ , C. E. (2008). E f , - . , *320,* 110 113. :// . /10.1126/ .1154735

L , E. W., & J , M. R. (1999). T : H w - , . *P R , 106,* 119 159. :// . /10.1037/0033-295X.106.1.119

L , D., & L -M , J. (2016). : A R f . *R J , 8,* 122 131.

M , R., & I ff, J. (2005). C f , . *C , 9,* 296 305. :// . /10.1016/ .2005.04.010

MQC , T., & B , T. (2016). E , w - f , . *C , 20,* 641 642. :// . /10.1016/ .2016.06.008

MQD , J. H., & S , E. P. (2011). S , , f : E f , . *N , 71,* 926 940. :// . /10.1016/ .2011.06.032

M , J. E., C , L. A., & MQA , J. D. (2013). W w , f w : L , , f . *P , 24,* 1118. :// . /10.1177/0956797612446707

M , A. K., C , B., & H , H. A. (1981). M f , f f . *P & P , 30,* 33 38. :// . /10.3758/BF03206134

N , Y., H , G., H , G., & S , T. (1992). T - : A , f . *P & P , 51,* 504 507. :// . /10.3758/BF03211646

N , Y., H , G., S , T., Y , K., K , M., S , M., & S , D. (2004). T - : T f , . *P , 33,* 1061 1079. :// . /10.1068/ 5061

N , A., & M , E. K. (2003). C , f , : C , f f . *N , 37,* 149 157. :// . /10.1016/S0896-6273(02)01144-3

N , A., & M , E. K. (2004). A - f w f , f . *P N A A , 101,* 7457 7462. :// . /10.1073/ .0402239101

O , V., B , P., Z , M., & R , B. (2012). A , , . *N , 50,* 36 43. :// . /10.1016/ . , .2011.10.019

P , C. V., & E , M. O. (2016). C , f . *N C , 7,* 11543. :// . /10.1038/ 11543

P , C. V., S , C., & E , M. O. (2012). W , . *C B , 22,* 46 49. :// . /10.1016/ .2011.11.039

P , F. H., G , S., & S , K. E. (2015). A B , . *C , 19,* 285 293. :// . /10.1016/ .2015.03.002

R , G. H. (2003). A f , . *J N , 89,* 1078 1093. :// . /10.1152/ .00706.2002

R , G. H. (2009). I f , . *H R , 258,* 89 99. :// . /10.1016/ .2009.04.009

R , L. J. (2013). H w ? S f , . *J E P : L , M , C - , 39,* 1257 1264. :// . /10.1037/ 0031143

R , N. W., H , J., & M G w, P. V. (2006). R , f : A , f , f - , . *P B , 273,* 2159 2168. :// . /10.1098/ .2006.3578

R , N. W., M G w, P. V., W , D. J., & H , J. (2017). G f f B . *P N A A , 114,* 412 417. :// . /10.1073/ .1610706114

R , L., & M , D. (2017). T f : E f . *J N , 37,* 10636 10644.

S , Z., & B , D. (2016). P , f , . *C O B , 8,* 200 206. :// . /10.1016/ .2016.02.014

S , Z., C , L., & M: , H. J. (2010). A , f , T , ff : T f f . *E B R , 203,* 723 735. :// . /10.1007/ 00221-010-2286-3

S , Z., C , , R. M., & M , W. H. (2013). B f
. C , *17,* 556 564. :// . . /10.1016/ . .2013.09.009

S , T. (1964). A f , f , f *145,* 1328 1330. :// . . /10.1126/ .145.3638.1328

S , D. A., & R , G. H. (2001). T - f ff . *N R : F R C* - *N R , 12,* 7 10. :// . . /10.1097/ 00001756-200101220-00009

W , V. (2003). A f : C , f , . C , *7,* 483 488. :// . . /10.1016/ . .2003.09.002

W , R. B., D H , L. D., & W , D. H. (1986). C f , . *P & P* - , *39,* 294 300. :// . . /10.3758/BF03204939

W , F. A., & H , N. J. (2001). T f : I. F , , , f . *P & P* , *63,* 1293 1313. :// . . /10.3758/BF03194544

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