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The e ec f ce c g ' e ea g Ch e e eech f f a a g ☆

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Abstract

I a c c a - a' e ' e , h a e a' e ab e e' ce a - e e a d c g e- e e c e' eg' ega e he a e ded a' ge eech f f he' bac g d c e a . A he c g e e e, ' g he e' h a' f he a' ge eech e ca a' ed ' e he' ec g f he' e a g a' he he a' ge eech a d c e g eech a' e ' e e ed a he a e. He ce, f edge f c e (c e c g) ' e' eech' ec g f he he' e e a' e a g. I add , fa a' f edge f he ce cha' ac e' c f he a' ge a e' c d a' he he e e' a e d f he a' ge a e' he he' a e a' e ' e e . The ' e' d e' ga ed he e e f h ch a c g e- e e c e (c e c g) a d a e' ce a - e e c e (ce c g) ca ' e f d de ' ca f f eech a ed b e f b he' eech Ch e' e e' e . S ec ' ca , e e' e' e ' ed h a' f a' e e ce e e bef e a' e e ce a ' e ea ed he ' e' e ce f e he' e f eech. The ' g e e ce a a he' a e ce a he a ge' e e ce. T d f ' e' e' e ga ed: a e- e e ce ' e' , a d d e' e - e e ce ' e' . U de' eech- a g c d , each f he ' e e' g ' ca ' ed ' ec g f he a' e d he f - e g h a ge' e e ce. U de' e- a g c d , a e- e e ce ' e' had a ea b g ' ca ' ea g e ec , b d e' e - e e ce ' e' had a eg g b e' ea g e ec . The e' e' gge ha add c e c e' , ce c ca be ed b Ch e' e e e' ' ea e' eech f a g b he' a e' .

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Keywords: S eech; I f a a g; E e' ge c ' g; C g e ec ; V ce

1. Introduction

1.1. Energetic vs informational masking

U de' e g c d ', e e' a ' d d c c ' ehe d a d a' c a e c e' a ', e ec a he he' e ea e a g, ch a a c c - a - a' e ' e . T a fac ' a' e h gh c ' b e h' d c : (1) e' ge c ' g f he a' ge' eech b - a' ge' d , a d (2) f a a e' fe' e ce f ' ' e e a a e' (f a a ' - g, A' b ga' e a ., 2002; B' ga' , 2001; B' ga' a d S ' , 2002; D' ach e a ., 2003; F' e a e a .,

☆ Pa' f h ' d ' e ed a he 4 h ee g f he Ac ' ca S c e f A e' ca a d he Ac ' ca S c e f Ja a .
* C ' e d g a h . Add e' : De a' e f P' ch g , Na a Ke Lab a ' Mach e Pe' ce , S eech a d Hea' g Re ea' ch Ce e' , Pe g U e' , Be g 100871, Ch a. Te .: +86 10 6275 6804; fa : +86 10 6276 1081.
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1999, 2001, 2004; K dd e a ., 1994, 1998; L e a ., 2004; L , 1990; O e ha e a ., 2003; Sh -C gha e a ., 2005; S e a d M , 2004; W e a ., 2005). E e ge c a g cc he e he a e a ac e c ed b a g a e he ed b ha e c ed b a - e , ead g a deg aded he g a , a g d c f b e e c g e -

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ab e e be e fe . He ce, he e e be g ea e e - e e a a he f da- e a f e e c (F_0) a Ma da Ch e e e a ce, he e each ab e ha ch c e , ha a E g h e a ce, he e he ch c e e fe ac e ab e . I e e ha a e d e h e ec he F_0 cha ge d g a e a ce (he F_0 c e - e), a d ha d e e ce F_0 c e be ee a a ge a e a d c e e g a e ca fac a e ac g e he a ge a e he he e a e c e e g a e (A a a d S e e d, 1989; Da a d H , 2000; Da e a ., 2003). He ce, beca e he e e g ea e a ab he F_0 c e e Ch e e ha E g h, he ef e e h c e a d e ac e he e a g age .

I add e , c e e a Ma da Ch e e, a a ge be e e d a e e cha ac e c e d d h ch each e he e cha ac e (e ab e) ha e a c e e e a e . F e a e, he Ch e e e d fe "Be g" a e ab e (/Be 3/ a d /J g1/)

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he e e a d e e ada dde ed f he a c a .

2.2. Apparatus

L e e e ea ed a cha a he ce e f a ec- h c cha be (Be g CA Ac c), h ch a 560 c e g h, 400 c d h, a d 193 c he gh . A ac c g a e ed g ed a he a g a e f 22.05 H g he 24-b C ea e S d B a e PCI128 (h ch had a b - a -a g f e) a d a d ed g f a e (C ed P 2.0), de he c a f a c e h a Pe IV ce . The ac c g a e de e ed a d- ea e (D a d Ac c , BM6 A), h ch a he f a a ha a e a 0° (h ec he ed a a e). The d ea e he gh a 106 c , h ch a a a e ea e e f a ea ed e e ha e age b d he gh . The d a ce be ee he d ea e a d he ce e f he a c a head a 185 c .

2.3. Stimuli

2.3.1. Chinese nonsense sentences

S ech e e Ch e "e e" e e ce . D ec E g h a a f he e e ce a e a b de ca he E g h e e e e ce ha e de e ed b He fe (1997) a d a ed d b F e a e a . (1999, 2001) a d L e a . (2004). Each f he Ch e e e e e ce ha h ee e c e : b ec , ed ca e, a d b ec , h ch a e a e he h ee e d, h cha ac e f each (a e - ab e f each cha ac e). N e ha he e ce f a ed e a c e a f ec g f he e d.

Ba ed he da aba e f he Ch e e a e *People's Daily* b hed e 9 ea (1994 2002), 6000 d b e- ab e e b, h ch e e a ed a ha gh gh f e- e ce f cc e ce, a d 12,000 d b e- ab e , h ch e e a a ed a ha gh gh f e ce f cc - e ce, e e ed. The e d e e c b ed a d 6000 ac ca c ec e e ce h he f a e f *subject + predicate + object*. T e e ha e e ce ed e e e e e ea gf , he b ab f c- cc e ce f ha e b a a e - e ce a de ed acc d g he da aba e f *People's Daily* e 9 ea . O e e ce h e b ab f c- cc e ce f e d he da aba e a e e ed a he e e e e ce f he e d . S ce Ch- e e a a g age, f he e ec a ade ba- a ce ab e e ac e e ce . A d b e- ab e a he aced bef e a , a d a a e b a aced bef e a e b, a g a ee ec ed e e ce e a a. F a , a e e ce e e a ed b he e e e e e e ha e ec ed e e ce e e ca .

B h a ge eech a d d e e - e e ce c g eech ed h d e e e b a g fe a e a e (Ta e A). Ma g eech a a c ec d g f a g Ch e e e e e e ce a e e b he f g fe a e a e (Ta e B a d C). Ta e B a d Ta e C e d e e a g e - e ce . A eech e e ec ded d g a cc - e d , a ed a 22.05 H a d a ed a 16-b PCM a e e .

T e -f (18 e ce /) f e e e - e ce e e ed a a ge e e ce . T ba a ce f a- a ac e e a c d h d, he f a a f a e d a e e ce a ca c a ed a

$$I = 20\lg\left(\frac{1}{f}\right)$$

he e f d f e c . I f a a f a e - e ce a he f f a a e f he h ee e d. A he f e e e e ce e c - c ed ch a a ha he f a a f a each a ab he a e. I a a ge e e ce, he a e d a c ed d g eech ec g e g. T e a e he e ce h e ec a d b , a e ce e e ca ed ha e he a e RMS a e, a d a e ce (b h a ge a d c g) e e ed a he a e dec be e e (52 dBA).

I he a e- e e ce c g c d , he e, h ch a e b Ta e A, a de ca he a ge e - e ce e ce ha he a e d a e aced b a h e eb , h ed a a e a ha f he ge f he a (h d) e d a he a ge e e ce, a d h e e e a 10 dB e (b h e e ce a d e e ea ed dBA) ha ha f he ced g e e ce (f g F e a e a ., 2004). I he d e e - e ce c g c d , a e e e e e ce, h e c e a d e e f ha f he a ge e e ce, a a e b Ta e A, h a he a ec (c d g he ace- e f he a e d h e e) be g de ca he a e- e e ce c g c d (F g. 1). O e h d ed a d f -f e e e e e ce e e ed a d e e - e ce c g eech a e a . F g. 1 h e he a ef f e f he a ge e e ce, he a e- e ce e, a d a d e e - e ce e, e ec e .

2.3.2. Speech-spectrum noise

Th ee h d ed f e e cc g ab e e ch- e f he da aba e f *People's Daily* b hed f e ea . O e h d ed a d h ee e e ce, h ch a ea ed *People's Daily* a d c a ed 317 ab e c d g a he 300 f e e cc g ab e, e e ec ed a ac c a e a f a g eech- ec e . The 113 d e e e ce e e g ed 50 Ch e e g fe a e ea e . F f - e e e ce e e e b 25 ea e a d 56 he e e ce e e e b a he 25 ea e a a ed a e f eech. Rec d g f he e ce e e ed g a cc e d , a - ed a 22.05 H a d a ed a 16-b PCM a e e . A f he 50- ce e e ce e e ed g Ma ab

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F a , he ... gh ... a e ... he e ce age ... he h e ... d a c ec de ed a a f c ... SNR. Aga , b h he a e- a d d e e -e e ce ... a ea ... de ... e e ea e f b h e a d eech a e . H e e , he a ... e ea e a ea be a e ha ha b e ed he he a d ec d ab e e e c de ed e a a e .

T de e e he he he ch e c f c h Fig. 2 a cha ac e ed he d d a a c- a , e d d a ch e c f c a he c d . Fig. 3 h h ea h e h d a e (μ) a ed h a e e a d g c d f he a d ec d ab e c de ed e a a e . I a h ee g c d , a d f b h ab e , e h e h d e e b e ed f eech a e c a ed e a e . A e ec e he e a e , he h ghe h e h d e e b e ed he e he 57

[illegible]

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f[illegible] [illegible]e c[illegible] ed a[illegible] g [illegible]ca e ec [illegible] [illegible] g e ($F[2,34] = 24.719$, $p = .000$), b [illegible] e ec [illegible] ab e ($F[1,17] < 1$) a d [illegible] [illegible] ab e b [illegible] e [illegible]ac [illegible] ($F[2,34] < 1$). He ce, he he a [illegible]e a [illegible] e, he e ec [illegible] he [illegible] g c[illegible] d [illegible] a he[illegible] a ef[illegible] [illegible] ab e [illegible] e a d [illegible] Pa [illegible] e *t*- e[illegible] (B[illegible] fe[illegible] c[illegible]ec ed) d ca ed ha he [illegible]- e c[illegible] d [illegible] d d [illegible] d e[illegible] g [illegible]ca f[illegible] he d e[illegible] e - e ce [illegible] e ($t[17] = 2.177$, $p > .05$), b ha d d d e[illegible] f[illegible] he [illegible]a e-[illegible] e ce [illegible] e ($t[17] = 7.081$, $p < .001$), a d ha he d e[illegible] e - e ce [illegible] e d e[illegible]ed g [illegible]ca f[illegible] he [illegible]a e-[illegible] e ce [illegible] e ($t[17] = 6.434$, $p < .001$). He ce, he he a[illegible] e[illegible] a[illegible] [illegible]e, he[illegible] a[illegible] e ea e f[illegible] a[illegible] g he a[illegible]a e-[illegible] e - e ce [illegible] e a[illegible] [illegible]ed, b [illegible] he a d e[illegible] e - e ce [illegible] e a[illegible] [illegible]ed.

The e[illegible] a e ANOVA f[illegible] he[illegible] eech a[illegible] e[illegible] f[illegible] d [illegible] [illegible] g [illegible]ca a e ec [illegible] [illegible] ab e ($F[1,17] = 1.447$, $p = .246$) b d d [illegible] d [illegible] g [illegible]ca e ec [illegible] [illegible] [illegible] g ($F[2,34] = 22.173$, $p = .000$), a d a [illegible] g [illegible]ca [illegible] a- b e × [illegible] g e[illegible]ac [illegible] ($F[2,34] = 15.570$, $p = .000$), d - ca g ha he e ec [illegible] [illegible] g a[illegible] [illegible] ge f[illegible] ab e [illegible] ha a[illegible] f[illegible] ab e [illegible] e. M e *t*- e[illegible] (B[illegible] fe[illegible] - [illegible] c[illegible]ec ed) c[illegible] [illegible] ed ha, f[illegible] he [illegible] ab e, he [illegible]- [illegible] e c[illegible] d [illegible] d e[illegible]ed g [illegible]ca f[illegible] he [illegible] [illegible] g c[illegible] d [illegible] ([illegible]- [illegible] e d e[illegible] e - e ce [illegible] e, $t[17] = 3.078$, $p < .05$; [illegible]- [illegible] e [illegible] a e-[illegible] e ce [illegible] e, $t[17] = 4.610$, $p < .001$), b ha he [illegible] [illegible] g c[illegible] d - [illegible] d d [illegible] d e[illegible] g [illegible]ca f[illegible] [illegible] e a [illegible]he[illegible] ($t[17] = 2.470$, $p > .05$). H[illegible] e e[illegible], *t*- e[illegible] (B[illegible] fe[illegible] c[illegible] - [illegible]ec ed) [illegible]ed ha a h[illegible] ee [illegible] g c[illegible] d [illegible] d e[illegible]ed f[illegible] [illegible] e a [illegible]he[illegible] f[illegible] ab e [illegible] ([illegible]- [illegible] e d e[illegible] e - [illegible] e ce [illegible] e, $t[17] = 3.484$, $p < .01$; [illegible]- [illegible] e [illegible] a e-[illegible] e ce [illegible] e, $t[17] = 6.864$, $p < .001$; d e[illegible] e - e ce [illegible] e [illegible] a e-[illegible] e ce [illegible] e, $t[17] = 4.336$, $p < .005$). M e *t*- e[illegible] (B[illegible] fe[illegible] c[illegible]ec ed) a[illegible] [illegible]c[illegible] [illegible] ed ha a h[illegible]gh he d e[illegible] e ce be ee he [illegible]- [illegible] e a d e[illegible] e - [illegible] e ce [illegible] e a[illegible] he a ef[illegible] [illegible] ab e [illegible] e a[illegible] a f[illegible] [illegible] ab e [illegible] ($t[1,17] = 2.218$, $p > .05$), he d e[illegible] e ce be ee [illegible]- [illegible] e a d a e-[illegible] e ce [illegible] e a[illegible] a[illegible]ge f[illegible] [illegible] ab e [illegible] ha f[illegible] [illegible] ab e [illegible] e ($t[17] = 5.010$, $p < .001$), a[illegible] a[illegible] he d e[illegible] e ce be ee he d e[illegible] e - e - e ce a d [illegible] a e-[illegible] e ce [illegible] e ($t[17] = 3.302$, $p < .05$). He ce, b[illegible]h d e[illegible] e - e ce [illegible] e [illegible] a d [illegible] a e-[illegible] e ce [illegible] e [illegible]d ce a [illegible]e ea e f[illegible] [illegible] eech a[illegible] g, h [illegible] a e-[illegible] e ce [illegible] e [illegible]d c g a a[illegible]ge [illegible]e ea e ha d f- fe[illegible] e - e ce [illegible] e, a d h he d e[illegible] e ce be ee [illegible]- [illegible] e a d [illegible] a e-[illegible] e ce [illegible] e, a d he d e[illegible] e ce be ee d e[illegible] e - e ce a d [illegible] a e-[illegible] e ce [illegible] e be g a[illegible]ge f[illegible] [illegible] ab e [illegible] ha f[illegible] [illegible] ab e [illegible] e.

Fig. 4 d ca e h[illegible] he [illegible] e a[illegible] a e e[illegible], σ, a[illegible] e[illegible] h a[illegible] e[illegible] e a d [illegible]- [illegible] g c[illegible] d [illegible] f[illegible] [illegible] ab e [illegible] e a d [illegible] f he a[illegible]ge [illegible]d. I ge e a [illegible] e[illegible] e[illegible] e ha [illegible] e[illegible] he he a[illegible] e[illegible] a[illegible] eech ha he he a[illegible] e[illegible] a[illegible] [illegible] e. I a[illegible] [illegible] a ea[illegible] ha [illegible] e[illegible] a[illegible] e[illegible] ee e[illegible] he he[illegible] [illegible] [illegible]- [illegible] e ha he he[illegible] e a [illegible] e. A h[illegible] ee-fac [illegible], h [illegible] - b ec ANOVA c[illegible] [illegible] ed ha he[illegible] e a[illegible] a g [illegible]ca a e ec [illegible] [illegible] a[illegible] e[illegible] ($F[1,17] = 86.348$, $p = .000$),

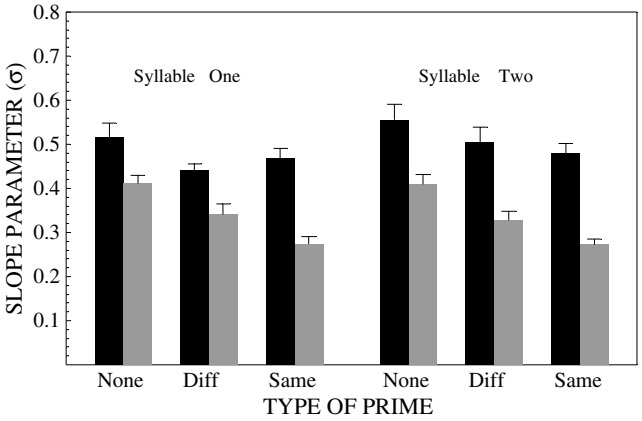

Fig. 4. A[illegible]e[illegible] [illegible]e a[illegible] a e e[illegible] (σ) a[illegible] a f c[illegible] [illegible] [illegible] he e[illegible] [illegible] a[illegible] e[illegible] a d e[illegible] [illegible] [illegible] e f[illegible] [illegible] ab e [illegible] e (ef) a d [illegible] ab e [illegible] (gh). S[illegible] d b ac [illegible]ec a g[illegible] [illegible]e[illegible] he da a f[illegible] he [illegible]e a[illegible] e[illegible]; gh e[illegible]ec a g[illegible] [illegible]e[illegible] he da a f[illegible] he[illegible] eech a[illegible] e[illegible]. E[illegible] [illegible] ba[illegible] d ca e he[illegible] a da[illegible] d e[illegible] [illegible] f he ea .

a[illegible] g [illegible]ca a e ec [illegible] [illegible] [illegible] g c[illegible] d [illegible] ($F[2,34] = 12.989$, $p = .000$), b [illegible] a e ec [illegible] [illegible] ab e ($F[1,17] = 2.305$, $p = .147$). The [illegible] e[illegible]ac [illegible] e ec ha a [illegible]ached [illegible] g [illegible]ca ce a he e[illegible]ac [illegible] be ee a[illegible] e[illegible] a d [illegible] ab e ($F[1,17] = 4.118$, $p = .058$), h ch [illegible] d be c[illegible] [illegible] e h he [illegible]b e[illegible] a [illegible] ha he [illegible] e d e[illegible] e ce[illegible] be ee [illegible] eech a d [illegible] e a e[illegible] gh be[illegible] gh a[illegible]ge f[illegible] [illegible] ab e [illegible] ha f[illegible] [illegible] ab e [illegible] e. M e *t*- e[illegible] (B[illegible] fe[illegible] c[illegible] - [illegible]ec ed)[illegible] h[illegible] ed ha [illegible] e[illegible] he [illegible] [illegible] g c[illegible] d [illegible] e[illegible] e ee e[illegible] ha h[illegible] e he d e[illegible] e - e ce [illegible] e [illegible] g c[illegible] d - [illegible] ($t[17] = 3.33$, $p < .05$), a d h[illegible] [illegible]e he[illegible]a e-[illegible] e ce [illegible] e [illegible] g c[illegible] d [illegible] ($t[17] = 4.72$, $p < .001$); b ha [illegible] e[illegible] he d e[illegible] e - e ce [illegible] e [illegible] g c[illegible] d [illegible] d d [illegible] d e[illegible] g- [illegible]ca f[illegible] h[illegible]e he[illegible]a e-[illegible] e ce [illegible] e [illegible] g c[illegible] d [illegible] ($t[17] = 1.65$, $p > .05$).

Fig[illegible]. 5 a d 6[illegible] h[illegible] h[illegible]e h[illegible]d a d [illegible] e[illegible], [illegible]e ec- e , cha ge a[illegible] a f c[illegible] [illegible] a[illegible] e a d [illegible] g c[illegible] d [illegible], he he h[illegible]e [illegible] d (b[illegible]h [illegible] ab e[illegible]) a c[illegible] de[illegible]ed. Fig. 5[illegible] gge[illegible] ha h[illegible] e h[illegible]d a[illegible]e [illegible] e[illegible] f[illegible] [illegible] eech a[illegible] e[illegible] ha f[illegible] [illegible] e a[illegible] e[illegible], a d ha, a[illegible] a[illegible] he ca[illegible] e f[illegible] he he [illegible] [illegible] ab e[illegible] e[illegible] e c[illegible] de[illegible]ed [illegible] e a[illegible] a e , he h ghe[illegible] h[illegible] e h[illegible]d [illegible]cc[illegible] he he[illegible] a[illegible] [illegible] e, f[illegible] [illegible] ed b he d e[illegible] e - e ce [illegible] e, h he [illegible] e h[illegible] e h[illegible]d [illegible]cc[illegible] g h he[illegible]a e-[illegible] e ce [illegible] e. A [illegible]-fac [illegible], h - b ec ANOVA c[illegible] [illegible] ed ha he[illegible] e a[illegible] a g [illegible]ca e ec [illegible] a[illegible] e[illegible] ($F[1,17] = 69.698$, $p = .000$), a[illegible] g [illegible]ca a e ec [illegible] [illegible] g c[illegible] d [illegible] ($F[2,34] = 18.379$, $p = .000$), b [illegible] g [illegible]ca e[illegible]ac [illegible] be ee a[illegible] e[illegible] e a d [illegible] g c[illegible] d [illegible] ($F[2,34] < 1$). M e *t*- e[illegible] (B[illegible] fe[illegible] c[illegible]ec ed) d - ca ed ha a [illegible] g c[illegible] d [illegible] d e[illegible]ed g [illegible]ca f[illegible] [illegible] e a [illegible]he[illegible] ([illegible]- [illegible] e d e[illegible] e - e ce [illegible] e, $t[17] = 2.895$, $p < .05$; [illegible]- [illegible] e [illegible] a e-[illegible] e ce [illegible] e, $t[17] = 5.877$, $p < .001$; d e[illegible] e - e ce [illegible] e [illegible] a e- [illegible] e ce [illegible] e, $t[17] = 3.618$, $p < .01$). He ce, h[illegible] h[illegible]d e[illegible] e [illegible] e f[illegible] [illegible] eech a[illegible] e[illegible] ha he e[illegible] e f[illegible] [illegible] e a[illegible] e[illegible], a d [illegible] e[illegible] he [illegible] e[illegible] e g e , d ca g

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ha he ˊ ë ˊ ded a ˊe ea e f a g. I add - , he a f ˊe ea e f a g a aˊgeˊ f a e- e ce ha f d eˊe - e e ce ˊ ë .

F g. 6 gge ha he e he h e d c d - eˊe ha e eˊ he he a eˊ a eech ha he a e, a d ha he eˊe a ha e eˊ he a ˊ e a ˊë e ed. A fac , h - b ec ANOVA c ed ha heˊe a a g ca a e ec f a eˊ e (*F*

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ab a cd .

4. Discussion

U de each f he cd he de , e- ce -c ec d de ca c ea ed h he c ea e f SNR f 12 dB 0 dB, h d a g a ea . The ab e ce f h he b h he a ge a d he a e eech a e e e- ce ed be e a a g f he a e ca ag ee- e h he e e ed b B ga e a. (2001), F e a e a. (2001), L e a. (2004), a d W e a. (2005). A c e h he e e e (e.g., B - ga , 2001; F e a e a., 1999; L e a., 2004; W e a., 2005), he e f he e d h ha he e f he ch e c f c f d de ca- a e ge e a ee e f he e a e ha he a e f he eech a e . O e e a a ha beca e he e c de ab e a a he e e g e e e f he eech a e , he a a e SNR h gh he he e a a e ced c a he a g eech, a d he a a e SNR he c g cc he a g eech. The e ec f he e c a- ca SNR d be a e he ch e c f c f a eech a e a c ed a ead - a e e a e , a d ca ed he f Rhebe ge a d Ve fe d (2005) a d Rhebe ge e a. (2006). (A ee d- c be d e ce be ee Ch e eech a d E g h eech).

4.1. The effects of priming in a noise masker

The e f he e d h ha a a e- e ce e d ce a a ge e ea e f a g ha a d e- e e ce e he he h e d c de ed. I add , hea f e ea e d e a a e- e ce e a a e a e he a e f ab e e (1.34 dB) a a f ab e (1.36 dB), a d gh e (1.10 dB) he he h e d a c de ed. S e e ee e he e a e d e e e- e ce a e- e ce e a g e . He ce, he g ca e ec be ed f e a e ha b h d f e ca ead a e ea e f a g he de f 1 dB he he h e d c ed, a d ha he e f he ch e c f c a e ha e e a e g e .

4.2. The effects of priming in a speech masker

Whe he a e a eech, he d c f a e (e he a e- e ce d e e- e ce) d- ced a ed c e f bh ab e ea d a- be a d f h e d c g. M e e e, he e e d e ce e be ee ab e e a d He ce, he he a e eech, he a a ec f g ed ce he e e f he ch e c f c .

The ec f a e h e hd a gh e c ca ed. F , a e- e ce e d ced a g ea e ea e f a g ab e ha ab e e (a 1.85 dB e ea e ab e e a d a 3.03 dB e ea e ab e). Sec d, a e- e ce e d ced a ge e ea e f a g ha d e- e e ce e ab e a d f h e d c g.

The ea ed ec e e f a e ab e he a e- e ce g c d d be ec ed f a c ec de ca f ab e e ea ed he e- hd f c ec de f g ab e I deed, χ^2 e d ca ed ha he ec d ab e a e e be c- ec de ed f he ab e eced g a c ec de ed. He ce, a e ec ed, he ec d ab e e ea de ed he he ab e c ec de- ed. P e ab , he c ec de ca f he a- be ed ce he ea ch e ghb h d f he ec d ab e, he eb fac a g he e ec e e f he g a a c g e- e e.

The e h e hd he he h e d c ed a ea be a e ha he (4.01 dB) e ed F e a e a. d (2004), f he 50% f he ch e c f c e a ed (1 dB e e). He ce, he g a he 50% h e hd, he e d e a ea be a g ca d e ce he he a e- e ce e e ed he e ce f a eech a e ha he a e ed he e ce f a e a e . H e e, beca e f he a e g f he ch e c f c he e ce f a e he he a e eech, he e a a be ee he e a d a e- e ce e he eech a e c d c ea e h dec ea g SNR. F e a e, he he e g , a c a he eech- a g c d c ec de ed 20% f he d a a SNR = 8.3 dB, he ea he he a ge e ce a eceded b he a e- e ce e, a c a e ab e de f 20% f he d a a SNR f 11.5 dB. He ce, fa ab e e g c d (20% f he d a e c ec de ed) he a e- e ce e a e de a 3.2 dB ad a age, h ch c e he 4.01 dB ad a age (f 50% c ec de ca) e ed b F e a e a. (2004). If he ec d ab e c d- e ed, he a e fa ab e e g c d (20% f he ec d ab e c ec de ed), he ad a age c ea e 4.7 dB. Th , e f he d e ce be ee e Ch e ea d E g h eech (ee be), e f he e d d ca e ha he ad a age f a e e- ce a d g a g eech ed E g h b a e e d Ch e e. S ce a b- a a e- e ce g ec ha bee b e ed b h a g age, a d e e g he e d e ce he ac c a he ea d g he e a f he a e a d a ge, e ha he ea e f a g d e e he a ac c fea e (h ch d e b a a he e a g age) b a he e a f h ghe - de ce e .

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ha d, edge f he c e f he e ce ca de ce a c e a a c g e e e (ch a g he he a ge d cc) he he e d c e ee a ed b a a e (ee F g. 2).

He ce, ba ed he e e e e ha a a e- e ce e e e ec beca e edge f he c e f he a f he e ce a d d ec- g a a h ghe -de c g e e e. S ec ca , edge f he a f he e a ca -a a e ce a he d d a ac he ce ha d c g he e e ce. A e ed b F e a e a. (2004), g he a ge - a e ce (fe a e), a a e ce, a f e he a e- e ce e ca e he a e a f e e ec g g he a e d he f a ge eech e ce (ab 4 dB) he he a e a - a e eech, d ca g ha he e ec a c e -c g e ec. Beca e h c g e ec a ea be de e de f he ce f he ea e a d he de f e a (a d a d a e bh ead a g), he c g c ea e e g e ce a a ce a (c g e) e e a he ha a a a d e e. H e e, he c e d h ha g he e e h he ce f he a ge e e ce (b e g a d e e - e ce he a e ce) ead a e a e a f a - g f Ch e e e e. He ce, edge f he cha ac- e c f a ea e ce fac a e d ec g beca e ead be e eg ega f he a ge a e ce f c e g a e , ce a a e ce a e e. He ce, f de a d he a e f a g Ch- e e a f ed E g h, e eed e a e h c- a d e e ce be ee Ch e e a d E g h ca a ec he deg ee h ch e e e he a g age a be e f fac h ch h d ce a e ea e f f a- a a g. C ea , e e eeded h e ec h e.

The e e d a h ha he g a g e , he h e h d f ec g g he a e d a e 1 dB e f a eech a e ha f a e a- e . O e gh ha e e ec ed a g ea e deg ee f a g b a eech a e ha b a e a e (F e a e a., 1999, 2004; L e a., 2004), a ea e a e deg ee f a g b he e a e (W e a., 2005), ce he eech a e ha b h e e ge c a d f a a a- g e ec a d he e a e ha e e ge c a g . H e e, a g ea e deg ee f c a he e e- e f he Ch e e eech a e ha he E g h eech a e a ha e ade ea e f he Ch e e a- c a e ac a ge f a (ee be). The ea- f h ha ha bee h ha e e ca be e f gh (e a ga) he a e he e g eech (G af a d A ge , 1994; H - a d-J e a d R e , 1993; Ne e a., 2003; S e a d M , 2004). If he Ch e e eech a e ed he e ha dee e a d de gh ha he E g h eech a- e , Ch e e e e ha e a g ea e be e f e g he gh ha d E g h e- e . I deed, a c a f dee gh f e e be ee he Ch e e a e eech a e ed he e d a d he E g h a e eech a e (F e a e a., 2001, 2004; L e a., 2004) d ca e ha he e a ea be a g ea e deg ee f a de d a- he Ch e e e e ha he E g h e e, a d he d a f he Ch e e gh a ea be ge ha h e f he E g h gh.[1] He ce, Ch e e e e gh d ea e hea he a ge eech he e ce f c e g eech ha a e a e e f a a f e beca e f he g ea e de h a d d a f he gh he Ch e e eech a e e ed he e ha he E g h eech a e ed e d (F e a e a., 2001, 2004; L e a., 2004). I a a e, h e e, ha a be fac , ch a eech a e, a ec he f e e c a d de h f gh a g age. He ce, a e ca a ha he Ch- e e eech a e e ed he e had dee e gh ha he E g h eech a e (ee Rhebe ge a d Ve fe d, 2005 a d Rhebe ge e a., 2006, f a d c f he e f gh he a g f eech b eech).

A a a , a g a he d g h he a- ge a d d ec e ec e a e a d he a ge , he eg ega e a ge eech f c e g eech (B - ga , 2001; F e a e a., 2004; K dd e a., 2005a,b). B ga a d c eag e (B ga , 2001; B ga e a., 2001) e ed ha he a a ge h a e a ed b e e e c e g h a e a e , f a

[1] T f ea a d gh, e f - a e ec ed 47 ec d a e f b h he a E g h eech a e, h ch e e ed he d b F e a e a. (2001, 2004) a d ha b L e a. (2004), a d he a e Ch e e eech a e ed he e d , bef e a g he h gh a 20 H e e ac he a de e e e f b h E g h a d Ch e e eech a e. The e a de e e e e he hed g a *r*- e g a e age e e ded b Ma he a ca (W f a Re ea ch, $r = 500$ a e). The hed a e e e he g a ad a c e a f c (Ma he - a ca, W f a Re ea ch). Th e a f c a he d e e - a ed f he a e , e., he a f he ea a d gh he a de e e e. I he fa h gh he a de e e e de ed.

T gh he eech a e a e e be ef e g he a ge eech, he dee e , de , a d e f e he a e. We ea ched f gh ha e e e ha 6 dB be he ea a de f he e e e. T de e he d h f he e dee gh, e a ed a he b f he gh a d ed a he a e bef e e c e ed he c e a e ha a e ha 3 dB ab e he f he gh. The e a h ch h a e a a e de ed he e b da f he gh. The e b da f he h gh a b a ed b e a g cce e a e f g he b f he gh e e c e ed a a e ha a e ha 3 dB ab e he f he gh. The e a h ch h a e a a e de ed he e b da f he gh. The d e ce be ee he e a d e b da e a a e a he d h f a gh. I he ca e ha gh e a ed, he e b da f he gh beca e he e b da f he ec d gh a d d b e c g f e e a dee gh. F g. 8 h he a dee e e f a eg e f he Ch e e eech a e, a d de e he ca a d d h f gh. The a a f e a dee gh a 19% f he Ch e a e b 10% f he E g h a e.

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[illegible] a he[illegible] ha e e[illegible]ge c a[illegible] g d[illegible] a ed e f[illegible] a ce, a d he a [illegible] [illegible]f a g a h gh de e de [illegible] he[illegible]-a[illegible] [illegible]f he a ge a d a e[illegible] [illegible]ce[illegible]. The[illegible]e[illegible][illegible] gge[illegible] ha e e he [illegible]ce [illegible]f he a ge a e[illegible] ca ha e a c g e ec [illegible] [illegible]ec[illegible]g g he a ge[illegible] eech[illegible] e ce he [illegible]e-e ce [illegible]f[illegible] eech [illegible]a e[illegible]. S ec[illegible]ca , he [illegible]e e[illegible] d[illegible]h[illegible] ha [illegible]e[illegible] g a d e[illegible]e[illegible] - e ce [illegible] e[illegible] g he a ge-a e[illegible] [illegible]ce ca[illegible] g [illegible]ca [illegible]e[illegible]ec[illegible]g [illegible] [illegible]f he a[illegible] e [illegible]d he f - e g h e ce [illegible] he he a-e[illegible] [illegible]-a e[illegible] eech. The[illegible]efo e, add [illegible] [illegible] e[illegible]ce ed [illegible] a a e a[illegible]a [illegible] (F[illegible] a e a ., 1999, 2001; L e a ., 2004; W e a ., 2005), a [illegible] [illegible] edge ab[illegible] a[illegible]ge [illegible]ca [illegible] (K dd e a ., 2005b), a d he f[illegible] a [illegible] a c[illegible] e [illegible]f he [illegible] e (F[illegible] a e a e a ., 2004; he [illegible]e e d), [illegible] edge [illegible]f he a[illegible]ge - a e[illegible] [illegible]ce ca a[illegible] [illegible] e e[illegible], [illegible] eech c[illegible] ca [illegible] he [illegible]e e ce [illegible]f a[illegible] g[illegible] eech he he a g age a[illegible] Ch e e. I [illegible] d be e[illegible]e g [illegible]ee he he[illegible] he[illegible] [illegible] a e[illegible] a e e ec [illegible]f [illegible]ce f[illegible] E g-[illegible] h [illegible] e e[illegible].

I [illegible] a [illegible] [illegible]e ha he e ec [illegible]f a d e[illegible]e [illegible]-e ce [illegible]a e-[illegible] e e ce [illegible] e d d [illegible] de e d [illegible] he [illegible]de[illegible] h ch c[illegible]d [illegible]e e e e ced. We [illegible] d ha e e ec ed[illegible] ch [illegible]de[illegible] e ec f he [illegible] e e e[illegible] ed [illegible] e ec [illegible]-a[illegible] b fa a[illegible] g he [illegible] e e[illegible] h he a[illegible]ge - a e[illegible] [illegible]ca cha ac e[illegible] c . F[illegible] f ha e[illegible]e he ca[illegible]e, e [illegible] d e ec [illegible] g [illegible] [illegible]d ce a a[illegible]ge[illegible] e ea e f[illegible] a[illegible] g he he [illegible]-[illegible] g c[illegible]d [illegible] [illegible] ceded he [illegible] [illegible] g c[illegible]d [illegible] ha he he [illegible]-[illegible] g c[illegible]d [illegible] f[illegible][illegible] ed he [illegible] [illegible] g c[illegible]d [illegible]. I he f[illegible] e ca[illegible]e, he [illegible]-e e[illegible] [illegible] d ha e [illegible]e [illegible]e [illegible] e[illegible] e e c g he [illegible]-[illegible] g c[illegible]d [illegible] a d he[illegible]efo e gh be e ec ed [illegible] h[illegible] a[illegible]ge [illegible] e ea e f[illegible] a[illegible] g ha he a e[illegible] ca e he[illegible] he a [illegible] [illegible]f e [illegible] [illegible] e [illegible] he a[illegible]ge - a e[illegible] [illegible]ce [illegible] d be e e[illegible] e bef[illegible]e he [illegible]-[illegible] g c[illegible]d [illegible] a e e[illegible] e ced. H[illegible] e e[illegible], beca[illegible]e he[illegible] e[illegible] e [illegible][illegible] de[illegible] e ec[illegible],[2] e ha[illegible] he [illegible]a d [illegible]a [illegible] [illegible]f e [illegible] [illegible] [illegible] e ced he a [illegible] [illegible]f [illegible] e ea e f[illegible] a[illegible] g.

5. Summary and conclusions

P[illegible]e[illegible] g a d e[illegible]e Ch e[illegible]e e e ce[illegible] [illegible]e b he a[illegible]ge a e[illegible] bef[illegible]e he a[illegible]ge[illegible] eech a[illegible] [illegible]e e ed fac - a ed [illegible] e e[illegible], [illegible]ec[illegible]g [illegible] [illegible]f each [illegible]f he a[illegible] e[illegible] ab e[illegible] he he a[illegible] e a[illegible] eech b [illegible] he he a[illegible] e a[illegible] [illegible]e. M[illegible]e[illegible], [illegible]e[illegible] g Ch e[illegible]e a[illegible]ge[illegible] eech h[illegible] he a e [illegible]d bef[illegible]e [illegible]e[illegible] g he f a[illegible]ge[illegible] e ce a[illegible][illegible] fac a ed [illegible] e e[illegible], [illegible]ec[illegible]g [illegible] [illegible]f he a[illegible] [illegible] a-b e a d he h[illegible]e [illegible]d, b h[illegible] fac a [illegible] e ec a[illegible] a e[illegible] he he a[illegible] e a[illegible] [illegible]e. Th[illegible], a [illegible] [illegible] - edge [illegible]f he a e[illegible] [illegible]ce a d/[illegible] he c[illegible] e [illegible]f he a[illegible]ge [illegible] eech [illegible]e[illegible] eech [illegible]ec[illegible]g [illegible] a Ch e[illegible] e “c[illegible]c - a - a[illegible]” e [illegible]e .

Acknowledgments

We a[illegible]e g a ef [illegible]H a Sh a d Y a -Sha Che g f[illegible] [illegible]gh f c[illegible] e a d d c[illegible][illegible], [illegible]X a L f[illegible] ech-ca [illegible], a d [illegible]We -J e Wa g a d Me g-Y a Wa g f[illegible] da a c[illegible]ec [illegible]. Th[illegible] [illegible] a[illegible] [illegible]ed b he Na [illegible]a Na [illegible]a Sc e ce F[illegible] da [illegible] [illegible]f Ch a (30670704; 60605016; 60535030; 60435010), he Na [illegible]a H gh Tech [illegible][illegible]g Re[illegible]ea[illegible]ch a d De e[illegible] e P[illegible]g[illegible]a [illegible]f Ch a (2006AA01Z196; 2006AA010103), he T a[illegible]-Ce [illegible] T a g P[illegible]g a F[illegible] da [illegible] f[illegible] he Ta e[illegible] b he S a e Ed ca [illegible] C[illegible] [illegible][illegible], “985” g a[illegible] f[illegible] Pe g U e[illegible], a d he Na [illegible]a Sc e ce[illegible] a d E g ee[illegible]-g Re[illegible]ea[illegible]ch C[illegible] c [illegible]f Ca ada.

Appendix A

I[illegible] g he[illegible] ch[illegible] e [illegible] c f c [illegible][illegible] e de e[illegible] ed he a e[illegible] [illegible]f μ a d σ ha [illegible] ed he Pea[illegible][illegible] χ^2 ea[illegible] [illegible]e [illegible]f g[illegible][illegible]d e[illegible] [illegible]f[illegible], he e

$$\chi^2 \quad \sum_{i \quad 1}^{n} \frac{\left(N_{x,i} \quad \frac{N}{1 \quad e^{\sigma x_i \quad \mu}}\right)^2}{\left(\frac{N}{1 \quad e^{\sigma x_i \quad \mu}}\right)} \quad \sum_{i \quad 1}^{n} \frac{\left(\frac{N}{1 \quad e^{\sigma x_i \quad \mu}} \quad N_{x,i}\right)^2}{\left(N \quad \frac{N}{1 \quad e^{\sigma x_i \quad \mu}}\right)},$$

N [illegible] he be[illegible] [illegible]f [illegible] a[illegible]e e ce a[illegible] [illegible]e[illegible] ed a a SNR x_i, a d $N_{x,i}$ [illegible] he be[illegible] [illegible]f c[illegible]ec de [illegible]ca [illegible][illegible] a ha SNR. The h [illegible]he[illegible][illegible][illegible] ha he da a a[illegible]e de-[illegible]c bed b a [illegible][illegible]g[illegible] c f c [illegible]. The be[illegible] [illegible]f deg[illegible]ee[illegible] [illegible]f f eed[illegible] a[illegible][illegible]c a ed h h χ^2[illegible] a[illegible] c[illegible] e[illegible] a [illegible] he be[illegible] [illegible]f SNR[illegible] [illegible] he be[illegible] [illegible]f a[illegible] a e e[illegible] e[illegible] - a ed. Whe e a[illegible]e [illegible] g a[illegible] ch[illegible] e[illegible] c f c [illegible] [illegible] he g[illegible] da a f[illegible] a[illegible] g e c[illegible]d [illegible], $N = 18 * 18 = 324$, a d $n = 4$. He ce he deg[illegible]ee [illegible]f f eed[illegible] a[illegible]e $4 \quad 2 = 2$.

T[illegible]de e[illegible] e he he[illegible] c[illegible]ec de [illegible]ca [illegible] [illegible]f he h[illegible]e [illegible]d c[illegible] d be [illegible]ed c ed f[illegible] he [illegible]bab [illegible] h ch he d d a [illegible]d [illegible]e c[illegible]ec de [illegible]ed, e ca c - a ed $y_{0,0,i}$, $y_{0,1,i}$, $y_{1,0,i}$, a d $y_{1,1,i}$, f[illegible] each [illegible]f he f[illegible] SNR[illegible] ($i = 1, 4$), he[illegible]e he [illegible][illegible] b c[illegible] ec [illegible]e he he[illegible] he [illegible][illegible] ab e a[illegible] c[illegible]ec de [illegible]ed (1) [illegible] [illegible] (0), a d he[illegible] ec[illegible]d[illegible] b c[illegible] ec [illegible]e he he[illegible] he[illegible] ec[illegible]d[illegible] ab e a[illegible] c[illegible]ec de [illegible]ed [illegible] [illegible]. Beca[illegible]e he[illegible]e a[illegible]e f[illegible] a -e c[illegible] e ca ega[illegible] e e ca ca c a e

$$\chi^2 \quad \sum_{i \quad 1}^{n} \frac{y_{0,0,i} \quad N * 1 \quad p1_i * 1 \quad p2_i \quad ^2}{N * 1 \quad p1_i \quad * 1 \quad p2_i}$$

$$\sum_{i \quad 1}^{n} \frac{y_{1,0,i} \quad N * p1_i * 1 \quad p2_i \quad ^2}{N * p1_i * 1 \quad p2_i}$$

$$\sum_{i \quad 1}^{n} \frac{y_{0,1,i} \quad N * 1 \quad p1_i \quad * p2_i \quad ^2}{N * 1 \quad p1_i \quad * p2_i}$$

$$\sum_{i \quad 1}^{n} \frac{y_{1,1,i} \quad N * p1_i * p2_i \quad ^2}{N * p1_i * p2_i}$$

[2] Se a[illegible]a e ANOVA[illegible] e[illegible] c[illegible]d c ed [illegible] he a e[illegible]age e[illegible]ce c[illegible]ec ach e ed each [illegible]f he[illegible] a[illegible] g × [illegible] e c d [illegible]chec f[illegible] a [illegible]de[illegible] e ec[illegible] f[illegible] b[illegible]h[illegible] ab[illegible] [illegible]e a d [illegible] I [illegible] e[illegible] he c[illegible] d [illegible]d he [illegible]de[illegible] [illegible] e[illegible] g[illegible] each[illegible] a[illegible] ca[illegible] g [illegible]ca ce.

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he e $p1_i$ a d $p2_i$ a e he bab e ge g ab e e a d c ec , e ec e , he he e ce a e e ed a SNR i. Va e $p1_i$ a d $p2_i$ e de e ed ha ed h χ^2. The be deg ee f f eed a each e e i 1 beca e he e a e f a -e c e ca eg e (3 deg ee f f eed), a d e a e- e a each e e f SNR ea g 1 deg ee f f eed f each SNR e e , a d 4 deg ee f f eed a .

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