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Intersensory binding across space and time: A tutorial review

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Abstract [illegible] *unity assumption* [illegible] *modality appropriateness hypothesis* [illegible]

Keywords [illegible]

Introduction

A [illegible] 2008 B [illegible] O [illegible] [illegible]

[illegible] (Ca [illegible], [illegible] & [illegible], 2004; [illegible], 2012; [illegible] & M [illegible], 1993). [illegible] ([illegible], 2012). [illegible] *immediate effect* [illegible] *aftereffect*. [illegible]

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5000 LE, [illegible], N [illegible] and
-a : [illegible]@ [illegible]

Spatial ventriloquism: Immediate effect

spatial ventriloquism.

capture … *mutual*

Temporal ventriloquism: Immediate effect

temporal ventriloquism.

Table 1 [illegible]

Table 1 ([illegible]d)

Effect	Task/Paradigm	Main Question	Finding	Sample Study
		Change in perception of causality		
	AV-TOJ	Storage/dissipation of aftereffect	Counterevidence (not delay) affects dissipation	Machulla, Di Luca, Froehlich and Ernst (2012)
	AV-TOJ	Role of spatial and contextual factors	Concurrent estimations and no location constraints	Roseboom and Arnold (2011)
	AV-TOJ	Attention modulation of temporal pattern	Spatially specific	Heron et al. (2012)
	Unimodal stimulus detection	Recalibration via change in processing speed	Auditory processing faster after sound-lag adaptation	Navarra et al. (2009)
	Finger tapping	Generalization of aftereffect	Synchronized finger tapping to flashes/clicks changed	Sugano et al. (2012)
	Magnitude estimation	Population coding in timing	Adaptation not uniform for each SOA	Roach et al. (2011)

[illegible], 2001). [illegible] (Fig. 2). [illegible], 2009). [illegible] (1959) [illegible] (B[illegible] & [illegible], 2007; K[illegible] & [illegible], 2008a). [illegible] *auditory driving*. [illegible] (5–40 Hz) [illegible] 5 and 40 Hz). [illegible] "*capture*" [illegible]

Table 2 [illegible]

	Space	Time
Relative strength	–Vision usually dominates audition, but mutual attraction can be demonstrated	–Audition captures vision
Temporal window	–Audiovisual stimuli need to be presented within ~−100 ms (sound-first) to ~+300 ms (sound-late)	–Somewhat narrower than for space
Spatial window	~±15° of horizontal separation, but with large variation	–Unconstraint by spatial disparity
Stimulus features	–Greater effect when sounds are difficult to localize	–Sounds with sharp transition
	–Visual stimuli can be presented in focus or periphery	–Visual stimuli preferably in periphery
		–Audiovisual rate <6 Hz
Aftereffect	–Space- and eye-specific (greater at adapted position)	–Modality-specific change in processing speed
	–Greater at adapted frequency, but with mixed evidence about transfer to other frequencies	–Smaller at adapted delay
	–Fast (after single exposure)	–Frequency specific
		–Space specific (simultaneous adaptation to sound-lead and sound-lag possible)
		–Probably fast (possibly after a few exposures)
Role of attention	–Direction of endogenous/exogenous shift of attention and shift in sound location can be dissociated	–Sounds preferably segregated with sharp onsets
	–But arrows and gaze can induce shift sound location as well	–Attention to the audiovisual timing relation increases aftereffect
	–Dual task with focused attention does not decrease the aftereffect	
Audiovisual congruence	–Phonetic congruency in speech: no effect	–Gender-matched speech: more fusion
	–Face orientation: no effect–	–Pitch/size congruence: more fusion for congruent pairs
	–Speech/nonspeech mode with sine wave speech: no effect	–Nonspeech like musical instruments: no effect of audiovisual congruency
	–Pitch/size congruence: greater effect for congruent pairs	

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2003; , 1964; , D H & a ,
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2003; & K , 2006), -
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R & P , 2002; g , g a &
2011; g a , K & , 2010, 2012), and
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2011; F a & D , 2008; G a , 2007;
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[illegible] (C[illegible], [illegible] & M[illegible], 2011; F[illegible] & D[illegible], 2008; K[illegible] & [illegible], 2010). C[illegible] [illegible] (G[illegible], 2007; [illegible] ., 2010). [illegible] (A[illegible] & B[illegible], 2003; R[illegible], 2005).

Spatial ventriloquist aftereffects

A[illegible]

[illegible]

[illegible]

Temporal ventriloquist aftereffects

[illegible]

… (2010) … (2011) … (2012) … & M G a, 2011). … 100- … 100- … OA … 0- … OA … 100 … 100- … 0- … OA … & Eg an, 2012, … (2012) …

[1] N … 2012; … 2003, 2005; … B d … d, 1989).

… 250 H … (250 H) … (300 H) … 2500 H … R b … and A n … d (2011) … *lagged* … *preceded* … H n, R a … , H n … n, M G a … and … (2012) …

Spatial and temporal criteria for intersensory pairing

… *not* … (C … & D d … , 2004; D … & … , 1980; … G an & P … , 2007). …

a −100 –+300 (−100 = ; +300 =),

15 (G ., 2003; H , N & , 2003; L & G , 2003; & R , 2001; R & B , 1977), (, , H , & , 2004).

F , , 200 , . C , M -Z . (2003) 200 (M -Z ., 2003).

double-flash ( ) 70 (., 2000).

and H (2007

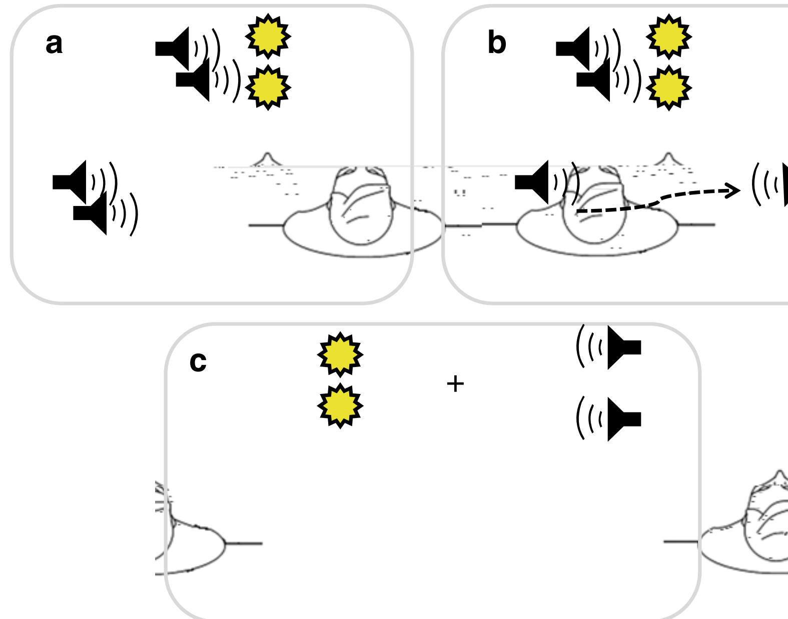

Fig. 6 [illegible] (*upper* [illegible] *lower*) [illegible] *nota* [illegible] (a), [illegible] (b), [illegible] (c). [illegible] & K [illegible], 2006)

[illegible] (B[illegible] et al., 2000a). [illegible] (F[illegible] & M[illegible], 2009; R[illegible] & B[illegible], 2009; [illegible] & [illegible], 2007). [illegible] (2012) [illegible] G[illegible] (2011) [illegible]

[illegible]

The putative role of attention for the spatial ventriloquist aftereffect

[illegible] K[illegible] and M[illegible] (2011) [illegible] *enhanced* [illegible]

The role of attention for the temporal ventriloquist effect

The role of attention for the temporal ventriloquist aftereffect

The role of cognitive factors for intersensory binding

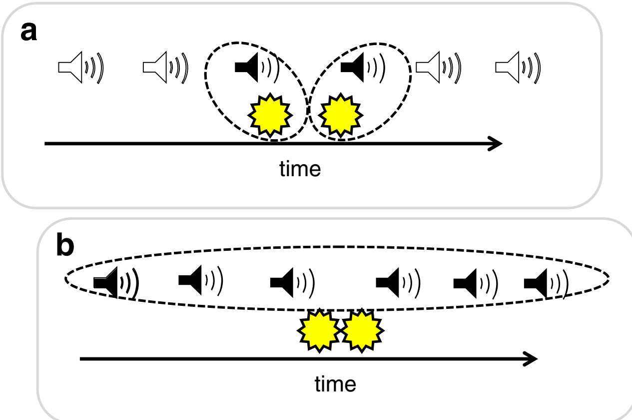

Fig. 7 [illegible] (K a., 2007)

[illegible]

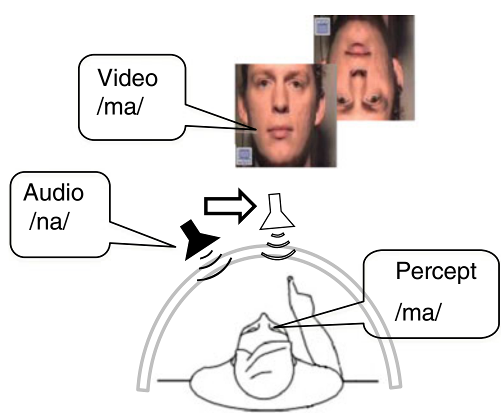

Fig. 8 [illegible] (B a., 1994)

The role of synesthetic congruency for intersensory binding

Theoretical accounts and models for immediate effect and aftereffect

[illegible] (Aa [illegible] & B[illegible], 2004; B[illegible] & Aa[illegible], 2006; [illegible] & A[illegible], 2007). [illegible]

[illegible] (Aa[illegible] & B[illegible], 2004; B[illegible], [illegible] & A[illegible], 2003; B[illegible] & Aa[illegible], 2006; E[illegible] & B[illegible], 2002; [illegible] a[illegible]., 2007; [illegible] & B[illegible], 2010; [illegible] a[illegible]., 2010; [illegible] & K[illegible]d[illegible], 2005). [illegible] Aa[illegible] and B[illegible] (2004) [illegible] K[illegible]d[illegible] a[illegible]. (2007) [illegible] (K[illegible]d[illegible] a[illegible]., 2007).

B[illegible] (B[illegible], M[illegible]d[illegible], [illegible] O[illegible] & M[illegible], 2005; [illegible], B[illegible], M[illegible] & [illegible] O[illegible], 2009). [illegible] 20 [illegible] (C[illegible], [illegible], M[illegible] & [illegible] O[illegible], 2002), [illegible]

[illegible] 1([illegible]) [illegible] (0[illegible]) J[illegible]

Computational approaches on temporal ventriloquism: Bayes and low-level neural models

Neural mechanisms in spatial ventriloquism

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