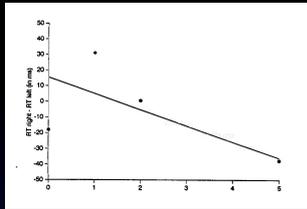


# Mechanisms of the SNARC effect

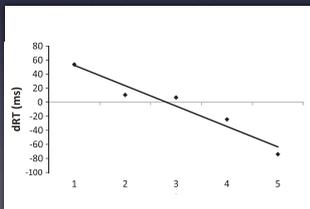
Wim Fias

Ghent University

1994



2011



## Classic explanation: the mental number line hypothesis

- long-term spatial representation of number magnitude: the mental number line

Hubbard, et al., (2005); Fias & Fischer (2005), de Hevia et al., (2008); Umiltà, et al., EBR (2009), ...

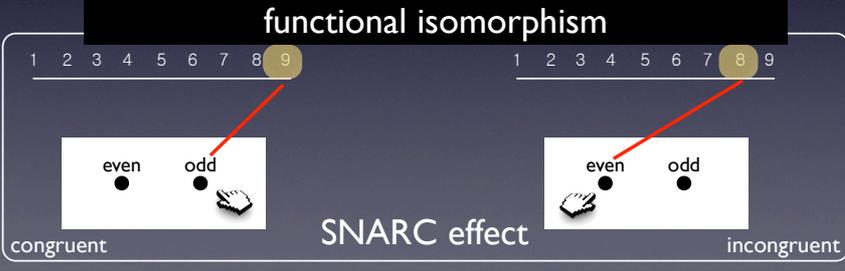
- functional isomorphism between number space and physical space

Priftis et al. (2005); Umiltà et al (2009), Zorzi et al. (2002)

- Common metric for representation of number and space: coordinate-based spatial representation

- involvement of a common mechanism for orienting spatial attention Zorzi et al. (2002), Fischer et al., 2003

# Mental number line can explain SNARC effect



## STUDY I: Nature of the spatial information that is associated to number

Conceptual congruency as an alternative to the MNL

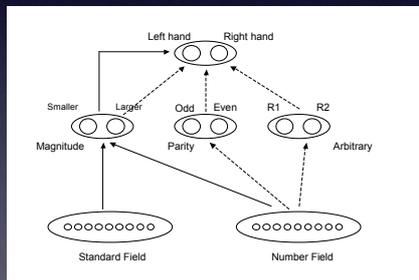
SNARC effect derives from congruency between conceptual categories, not from congruency between a position on mental number line and left or right response

Proctor et al. (2006): polarity coding

minus	plus
left	right
small	large
young	old
cold	hot
jin	jang

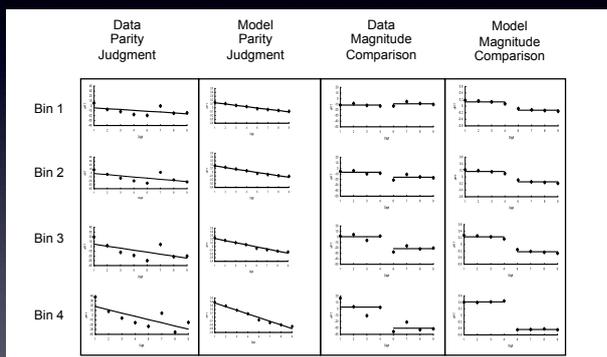
Kosslyn: categorical vs coordinate spatial processing

Paivio: dual coding: verbal vs analogue to sensory experience



Gevers et al. (2006)

model captures the data quite well



but that's no proof of existence

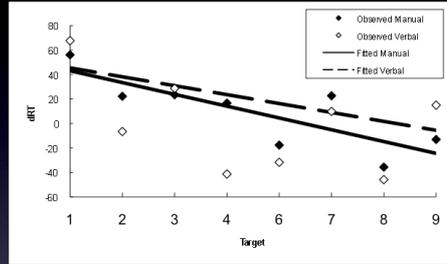
# conceptual vs. physical space

## EXPERIMENT 1

parity judgment

verbal responses: say left or right  
 manual responses: press left or right

within subjects



SNARC effect for verbal responses

==> number magnitude CAN interact with space at a conceptual level

No difference between verbal and manual responses

==> suggests that conceptual level is crucial determinant of SNARC

Gevers et al. (2010, JEP:General)

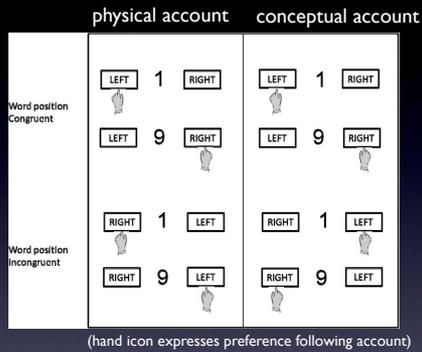
## EXPERIMENT 2: pitting conceptual space against physical space

parity judgment

response buttons variably  
 labelled "left" or "right"

task:

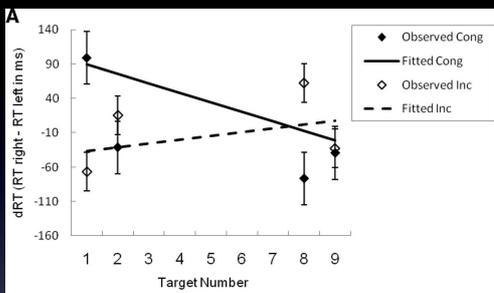
if even press on button labelled "left"  
 if right press on button labelled "right"  
 (or vice versa)



Does the SNARC effect follow

- position of the hand?
- or
- position of the labels?

Gevers et al. (2010, JEP:General)



SNARC effect determined by the words

Gevers et al. (2010, JEP:General)

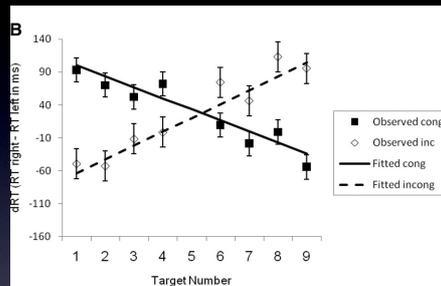
## EXPERIMENT 3: Pitting conceptual space against physical space

magnitude comparison

response buttons variably  
labelled "left" or "right"

task:

if  $< 5$ : press on button labelled "left"  
if  $> 5$ : press on button labelled "right"  
(or vice versa)



SNARC effect determined by the words

Gevers et al. (2010, JEP:General)

## conclusions study 1

- not the same metric as visuospatial representation of physical space
- originates from a more abstract level of processing
  - small/large vs left/right word associations
  - categorical spatial coding (as opposed to coordinate coding)
- what is the underlying mechanism?

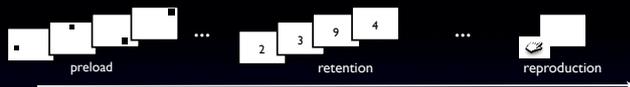
## study 2: working memory is necessary for the SNARC effect

Number-space associations are more flexible than one would expect  
from LTM representation

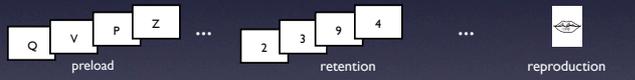
- range-dependent (Dehaene et al., 1993; Fias et al., 1996)
- dependent on visual imagery (Bachtold et al., 1998)
- flexibly depending on reading habits (Shaki et al.)

==> might indicate that spatial coding is not inherently associated to  
number but that it is constructed during task execution, suggesting a  
crucial role of working memory (WM)

### visuospatial working memory load

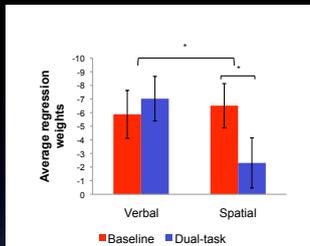


### verbal working memory load



during retention interval:  
parity judgment  
magnitude comparison

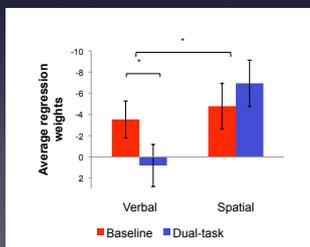
van Dijck, Gevers, & Fias (2009, Cognition)



#### magnitude comparison:

- SNARC effect disappeared under visuospatial load
- SNARC effect preserved under verbal load

cfr. Herrera et al., Acta Psychologica, 2008



#### parity judgment:

- SNARC effect disappeared under verbal load
- SNARC effect preserved under visuospatial load

van Dijck, Gevers, & Fias (2009, Cognition)

## conclusions study 2

- free WM resources are required for SNARC effect
  - magnitude comparison: visuospatial working memory
  - parity judgement: verbal working memory
- how can working memory account for SNARC effect?

van Dijck, Gevers, & Fias (2009, Cognition)

# study 3: Position in WM determines SNARC effect

## HYPOTHESIS

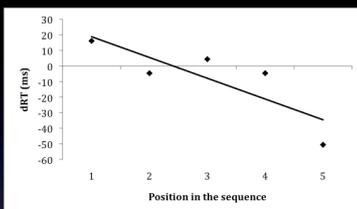
- numerically ordered task set is created and stored in WM
- positions in WM associated with space:
  - initial items - left
  - final items - right

van Dijck & Fias (2011, Cognition)

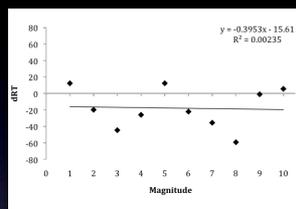
## experiment I



van Dijck & Fias (2011, Cognition)



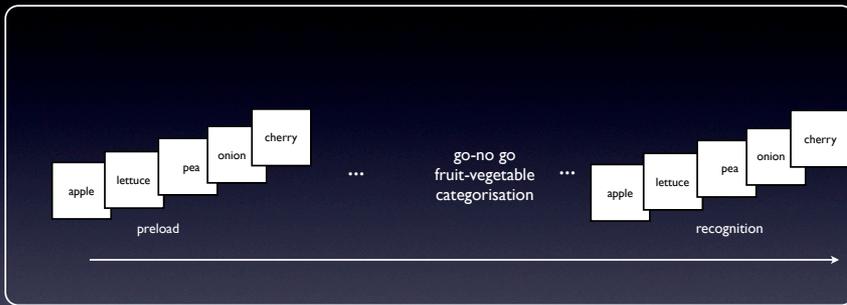
position in WM associated to left-right



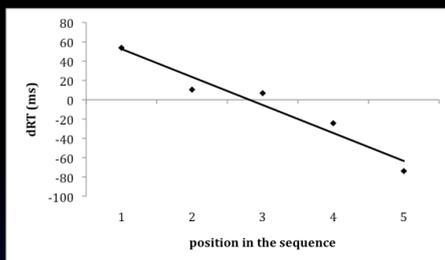
number magnitude not associated to left-right

van Dijck & Fias (2011, Cognition)

## experiment 2

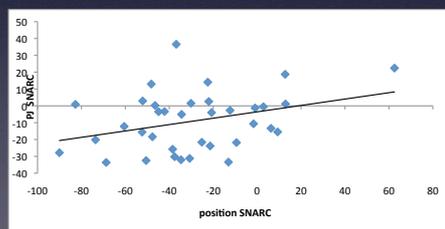


van Dijck & Fias (2011, Cognition)



position-space effect

+ standard parity judgement task to measure SNARC effect



position-space effect correlates with SNARC effect

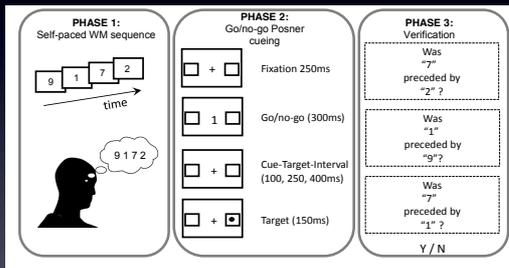
$r = .33$  (controlled for RT);  $P < .05$

van Dijck & Fias (2011, Cognition)

## conclusions study 3

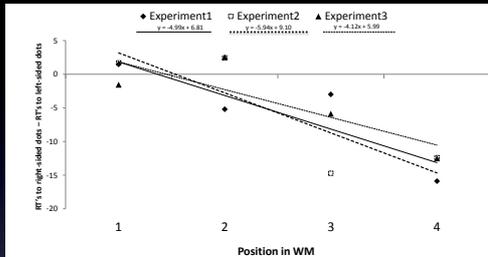
- it are the temporary position-space associations that drive the SNARC effect, rather than the long-term semantic representations of number to which the SNARC effect is traditionally ascribed
- Unitary explanation for:
  - dilution of SNARC effect under WM load (van Dijck, et al, 2009; Herrera et al.)
  - SNARC effect when number magnitude is irrelevant for the task (e.g. phoneme monitoring, Fias et al., 1996)
  - range-dependency (e.g. Dehaene et al., 1993; Fias et al., 1996)
  - dependency on imagery (Bachtold et al., 1998)
  - rapid changes of direction of SNARC effect (Shaki et al.)
  - SNARC effect with non-numerical ordinal information (Gevers et al., 2003; Van Opstal, et al., 2009)

# Study 4: spatial attention operating in the workspace



experiment 1 and 2: keypress  
 experiment 3: verbal responses ('yes')

van Dijck et al., in press, Psych Science

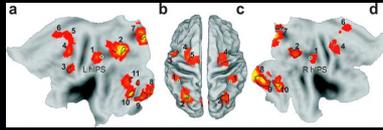


robust and replicable influence of WM position on spatial attention

see also poster of van Dijck

## neural basis

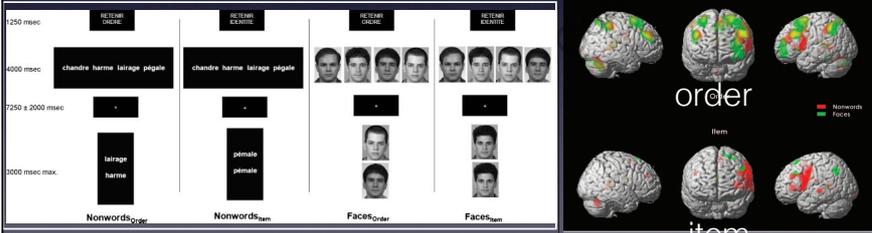
# comparison of ordinal information



Fias et al., JNS, 2007

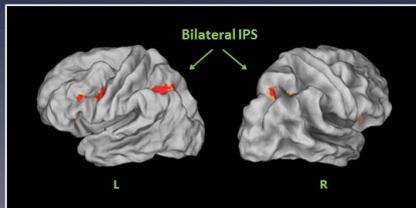
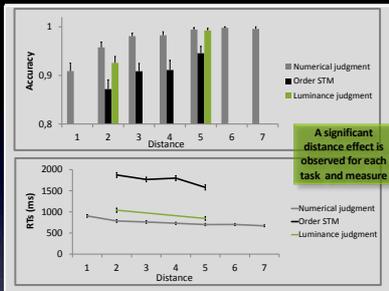
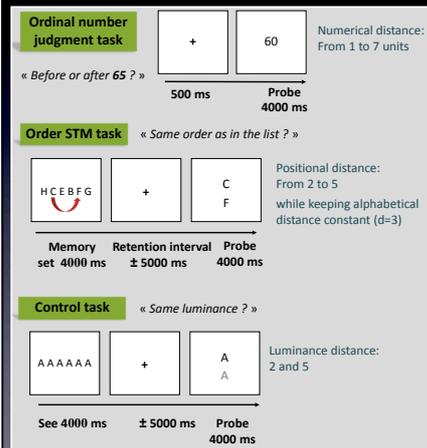
## overlapping neural circuits

### order processing in working memory



Majerus, et al, JOCN, 2010

## serial order in WM overlaps with number processing



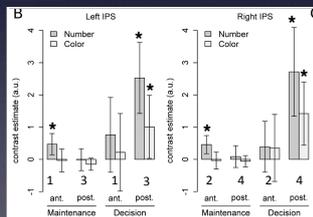
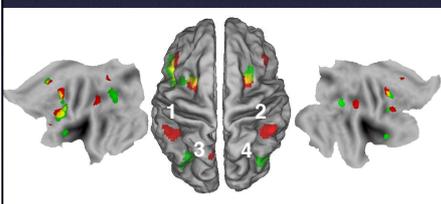
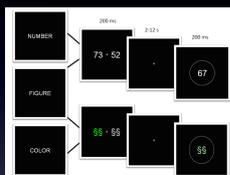
conjunction of distance effect in number and STM task (controlled for distance in luminance task)

Attout et al, in preparation

## 'workspace' involves spatial attention

### numerical landmark task

maintenance selection

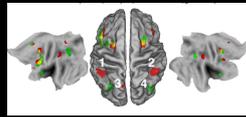
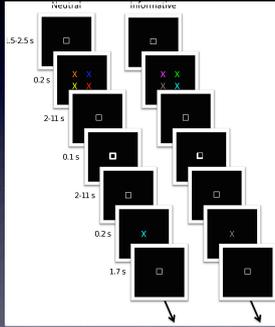


anterior IPS: maintenance, only for numbers  
 posterior IPS: selection, for numbers and colors

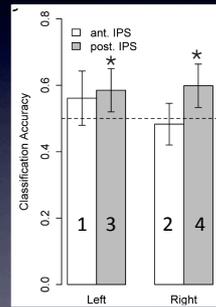
Seurinck, et al., in preparation

## attentional localizer

retro-cueing paradigm  
Nobre et al., 2004



multivoxel pattern analysis



posterior IPS : attentional orienting in mental representations

## conclusion

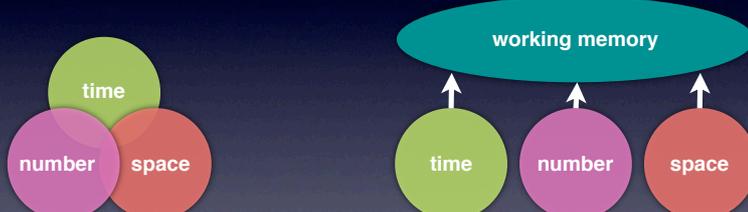
overlapping frontoparietal neural networks for number processing and processing serial order in WM

involvement of aIPS during maintenance

involvement of pIPS spatial attention mechanisms when orienting in workspace

## general conclusion

- spatial representations of SNARC effect are of categorical nature
- interactions between number and space occur at the level of working memory
- working memory might also be the convergence point of space, time and number



serial position provides the possibility to calibrate one dimension on the other

- Remaining questions:
  - number space interactions in other tasks: related mechanism?
  - number bisection
  - operational momentum
  - pointing

# Thank you!

- Jean-Philippe van Dijck (UGhent)
- Wim Gevers (ULB)
- Tom Verguts (UGhent)
- Ruth Seurinck (UGhent)
- Elger Abrahamse (UGhent)
- Steve Majerus (ULG)
- Lucie Attout (ULG)