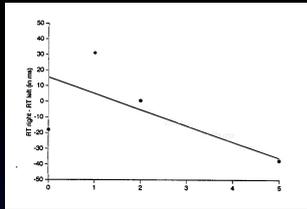


Mechanisms of the SNARC effect

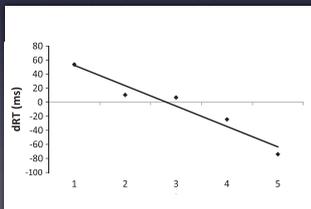
Wim Fias

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), ...

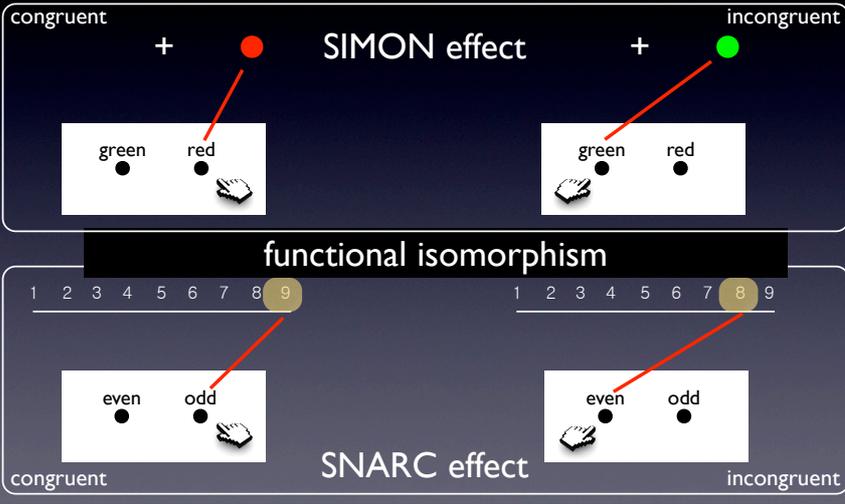
- functional isomorphism between number space and physical space

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

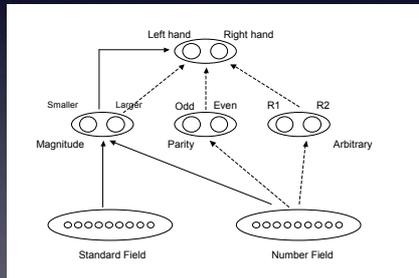
SNARC effect derives from congruency between conceptual categories, not from congruency between a position on mental number line and left or right response

Proctor et al. (2006): polarity coding

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

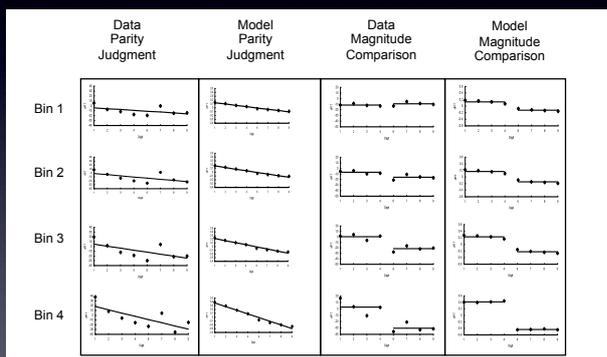
Kosslyn: categorical vs coordinate spatial processing

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

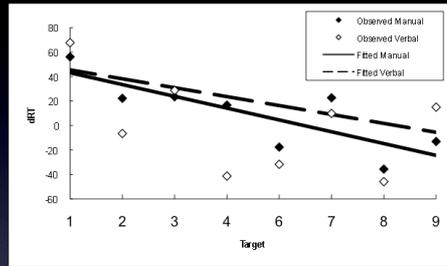
conceptual vs. physical space

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)

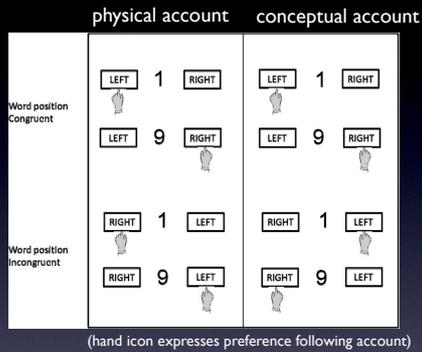
EXPERIMENT 2: pitting conceptual space against physical space

parity judgment

response buttons variably
 labelled "left" or "right"

task:

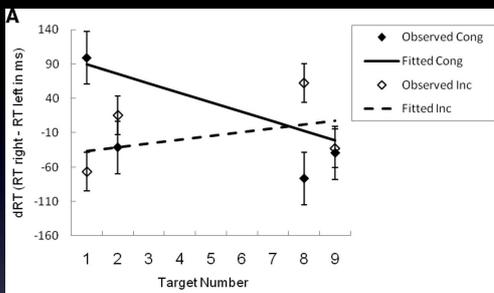
if even press on button labelled "left"
 if right press on button labelled "right"
 (or vice versa)



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)

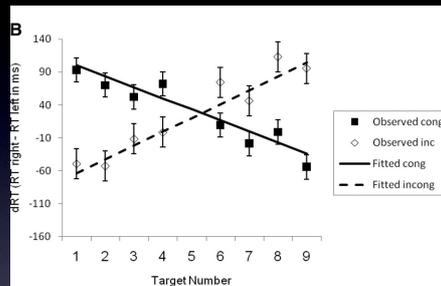
EXPERIMENT 3: Pitting conceptual space against physical space

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?

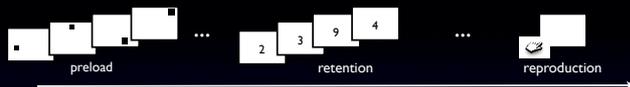
study 2: working memory is necessary for the SNARC effect

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

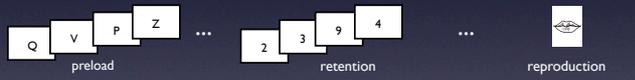
- range-dependent (Dehaene et al., 1993; Fias et al., 1996)
- dependent on visual imagery (Bachtold et al., 1998)
- flexibly depending on reading habits (Shaki et al.)

==> 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

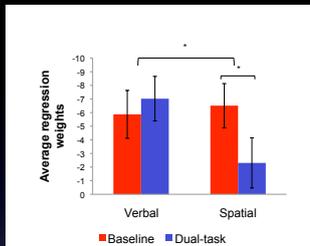


verbal working memory load



during retention interval:
parity judgment
magnitude comparison

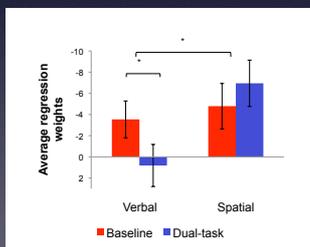
van Dijck, Gevers, & Fias (2009, Cognition)



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

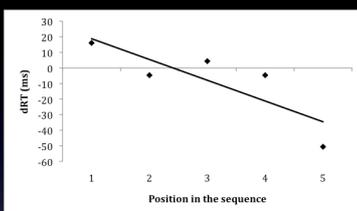
- numerically ordered task set is created and stored in WM
- positions in WM associated with space:
 - initial items - left
 - final items - right

van Dijck & Fias (2011, Cognition)

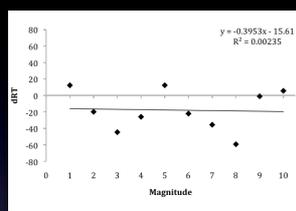
experiment I



van Dijck & Fias (2011, Cognition)



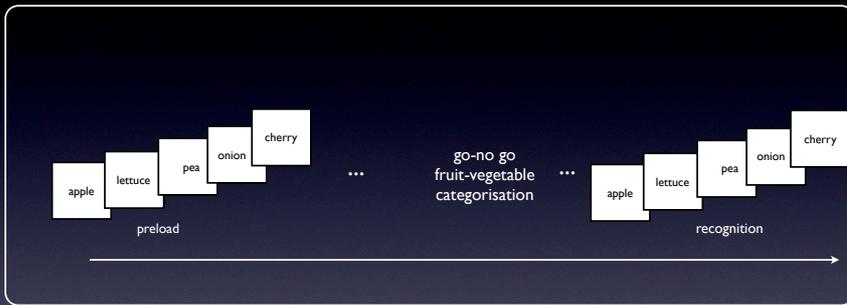
position in WM associated to left-right



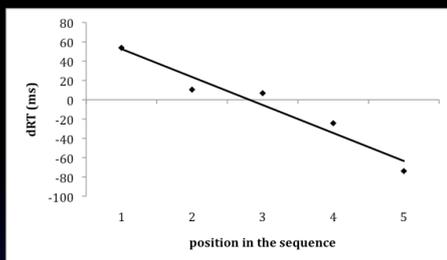
number magnitude not associated to left-right

van Dijck & Fias (2011, Cognition)

experiment 2

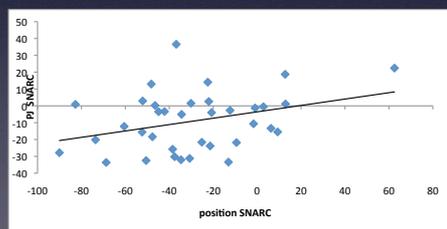


van Dijck & Fias (2011, Cognition)



position-space effect

+ standard parity judgement task to measure SNARC effect



position-space effect correlates with SNARC effect

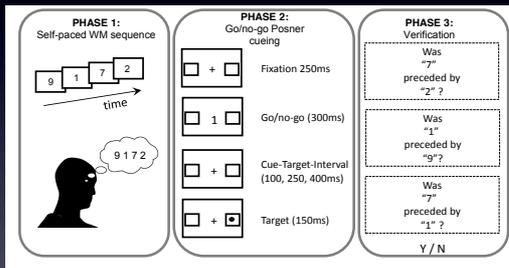
$r = .33$ (controlled for RT); $P < .05$

van Dijck & Fias (2011, Cognition)

conclusions study 3

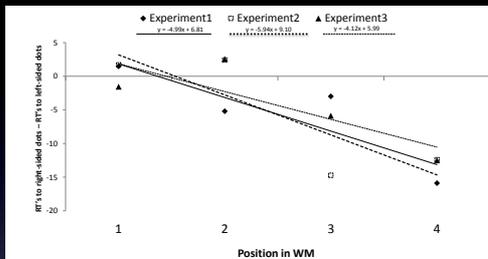
- it are the temporary position-space associations that drive the SNARC effect, rather than the long-term semantic representations of number to which the SNARC effect is traditionally ascribed
- Unitary explanation for:
 - dilution of SNARC effect under WM load (van Dijck, et al, 2009; Herrera et al.)
 - 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

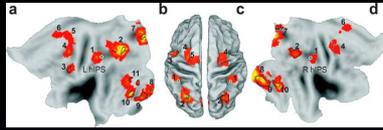


robust and replicable influence of WM position on spatial attention

see also poster of van Dijck

neural basis

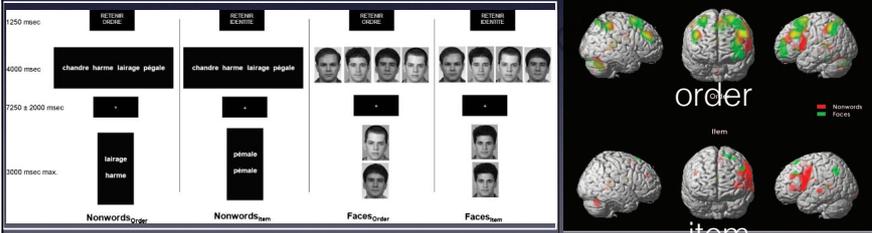
comparison of ordinal information



Fias et al., JNS, 2007

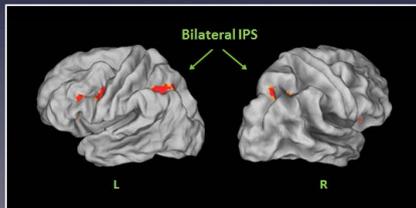
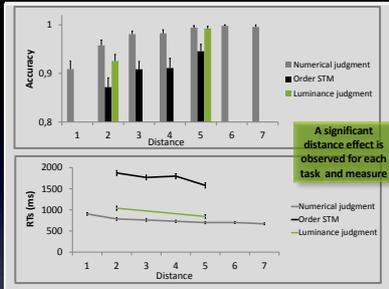
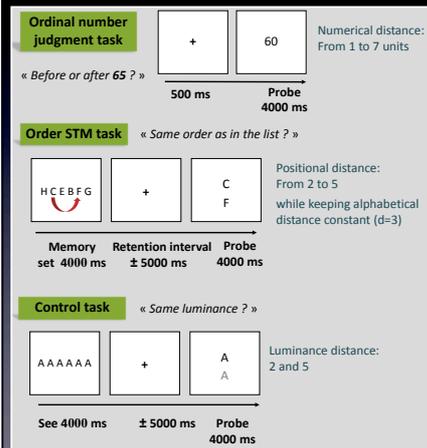
overlapping neural circuits

order processing in working memory



Majerus, et al, JOCN, 2010

serial order in WM overlaps with number processing



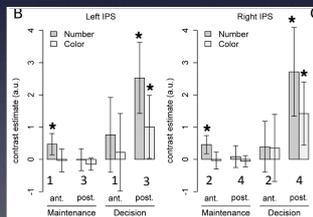
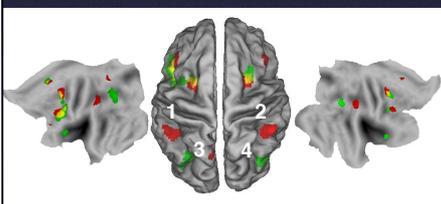
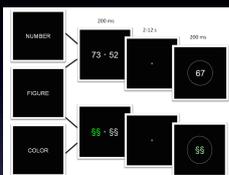
conjunction of distance effect in number and STM task (controlled for distance in luminance task)

Attout et al, in preparation

'workspace' involves spatial attention

numerical landmark task

maintenance selection

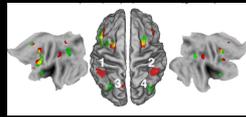
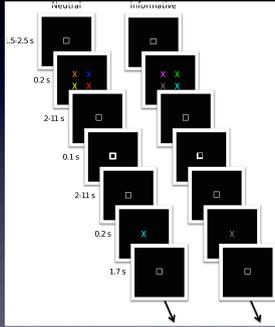


anterior IPS: maintenance, only for numbers
posterior IPS: selection, for numbers and colors

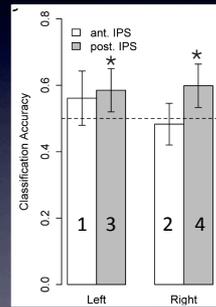
Seurinck, et al., in preparation

attentional localizer

retro-cueing paradigm
Nobre et al., 2004



multivoxel pattern analysis



posterior IPS : attentional orienting in mental representations

conclusion

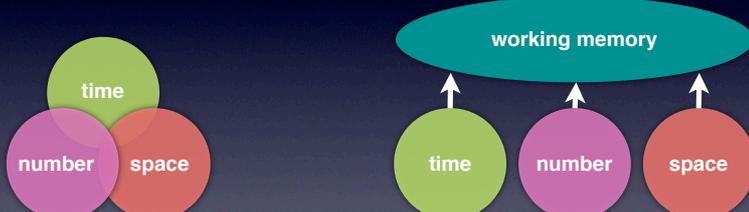
overlapping frontoparietal neural networks for number processing and processing serial order in WM

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)