Measuring the cost of deploying top-down visual attention

Dirk Walther[1,2,3,*], Li Fei-Fei[3], Christof Koch[1]

[1] Computation and Neural Systems, California Institute of Technology, Pasadena, CA, 91125, USA * walther@klab.caltech.edu, http://klab.caltech.edu/~walther
[2] Centre for Vision Research, York University, 4700 Keele Street, Toronto, ON, M3J 1P3, Canada
[3] Beckman Institute for Advanced Science and Technology, University of Illinois Urbana-Champaign, Urbana, IL, 61801, USA

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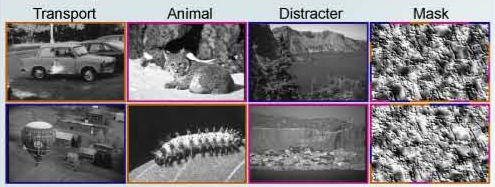
Introduction

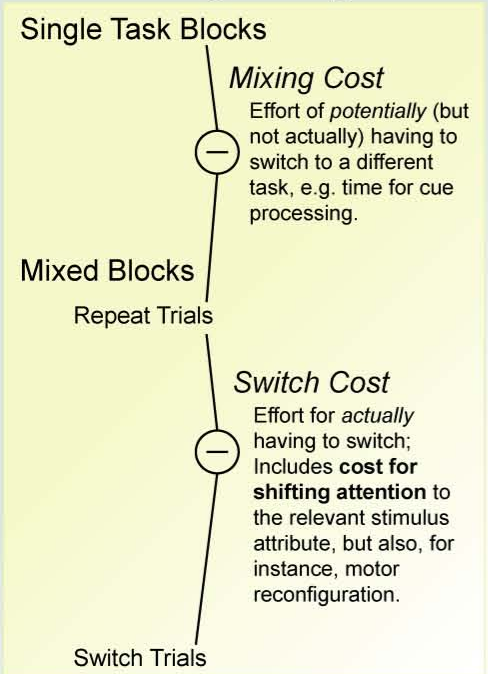
In many everyday situations we bias our perception using task-dependent information. To explore the cost involved in shifting top-down attention to a new task, we adopted a task-switching paradigm, in which 'switch' and 'repeat' trials in mixed task blocks are contrasted with single task blocks.

Example Stimuli



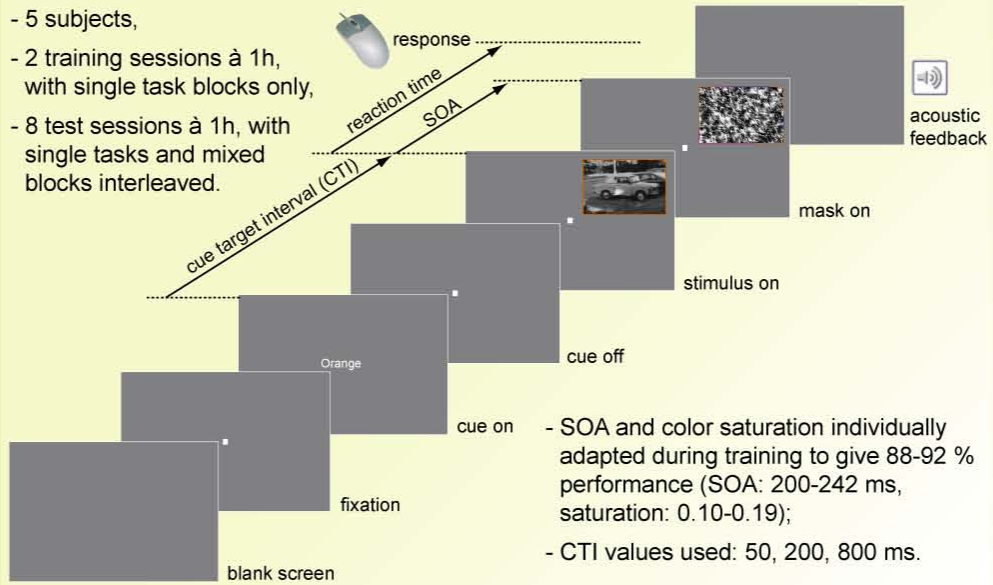
- Small set of stimuli set aside for training;
- More than 1000 images of each category used for testing;
- Each image shown at most twice.

Task Switching Paradigm



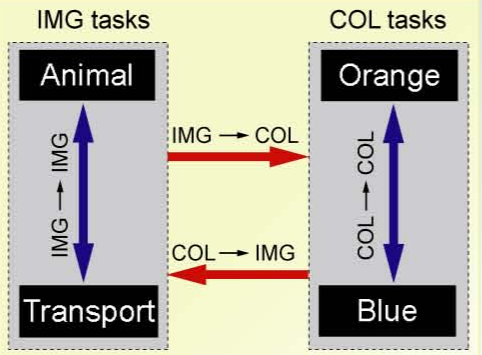
Experimental setup

- 5 subjects,
- 2 training sessions à 1h, with single task blocks only,
- 8 test sessions à 1h, with single tasks and mixed blocks interleaved.

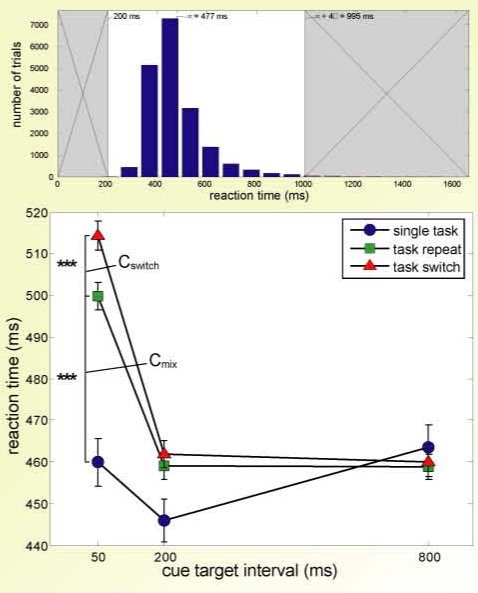


- SOA and color saturation individually adapted during training to give 88-92 % performance (SOA: 200-242 ms, saturation: 0.10-0.19);
- CTI values used: 50, 200, 800 ms.

Tasks



Reaction Times



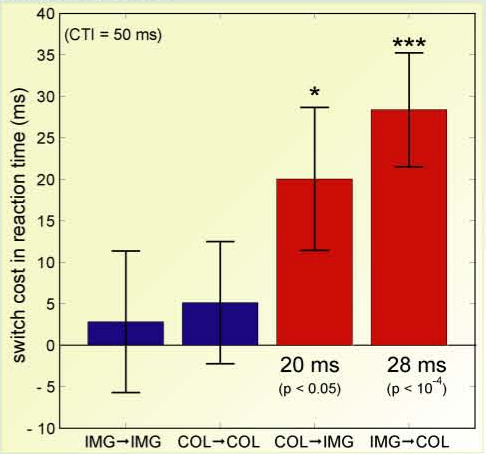
ANOVAs

Source		Mixing cost in reaction time			
	d.f.	*Mean square*	*F*	*p*	
CTI	2	4131	14.20	0.002	***
task group	1	2245	7.72	0.02	*
subject	4	1367	4.70	0.03	*

Source		Switch cost in reaction time			
	d.f.	*Mean square*	*F*	*p*	
CTI	2	915	3.79	0.03	*
task group	1	168	0.70	0.4	n.s.
subject	4	418	1.73	0.2	n.s.
switch condition	1	1914	7.93	0.009	**

Mixing cost absorbs most of the differences between subjects and between task groups; Switch cost does not depend on those but varies with switch condition (within/between attribute).

Switch Cost



Conclusions

1. Significant switch cost for between- but not for within-group switches; only difference: need to shift attention.
2. Cost of shifting attention here: 20-28 ms in RT.
3. Between-group switches: presumably earlier in processing hierarchy, re-route visual information.
4. Within-group switches: change biases in later areas, e.g. IT and PFC for object detection.

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We wish to thank Shinsuke Shimojo, Farshad Moradi, and Rufin van Rullen for insightful discussions. Lisa Fukui collaborated on early pilot studies. This project was funded by the NSF Engineering Research Center for Neuromorphic Systems Engineering at Caltech, by the NIH, the NIMH, the Keck Foundation, and a Sloan-Swartz Fellowship to D.W.

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[1] Computation and Neural Systems, California Institute of Technology,
Pasadena, CA, 91125, USA, [*] walther@klab.caltech.edu, http://klab.caltech.edu/~walther
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In many everyday situations, we bias our perception using task-dependent information. To explore the cost involved in shifting top-down attention to a new task, we adopted a task-switching paradigm, in which 'switch' and 'repeat' trials in mixed task blocks are contrasted with single task blocks. We use two visual tasks in our paradigm: object detection in cluttered gray-level natural scenes ('animal' vs. 'non-animal' and 'vehicle' vs. 'non-vehicle'); and discriminating the color of the frame enclosing these images ('orange' vs. 'purple' or 'blue', and 'blue' vs. 'orange' or 'purple'). We distinguished switch costs with (e.g. switching from detecting orange among purple/blue distracters to detecting animals in natural scenes) and without top-down attention shifts. We found significant switch costs in reaction time of 20 ms for switching from a color task to an object detection task ($p < 0.05$), and of 28 ms for switching from an object detection task to a color task ($p < 0.0001$). There are no significant switch costs for switches within a stimulus attribute, when no top-down attention shift is required. We conclude that deploying top-down attention to a different attribute incurs a significant cost in reaction time, but that biasing to a different feature value within the same stimulus attribute does not. ANOVAs of mixing and switch cost show significant ($p < 0.03$) differences among individual subjects for mixing cost, but no such effect for switch cost: shifting top-down attention has a fixed processing duration among individuals.