Perception, Cognition, Action

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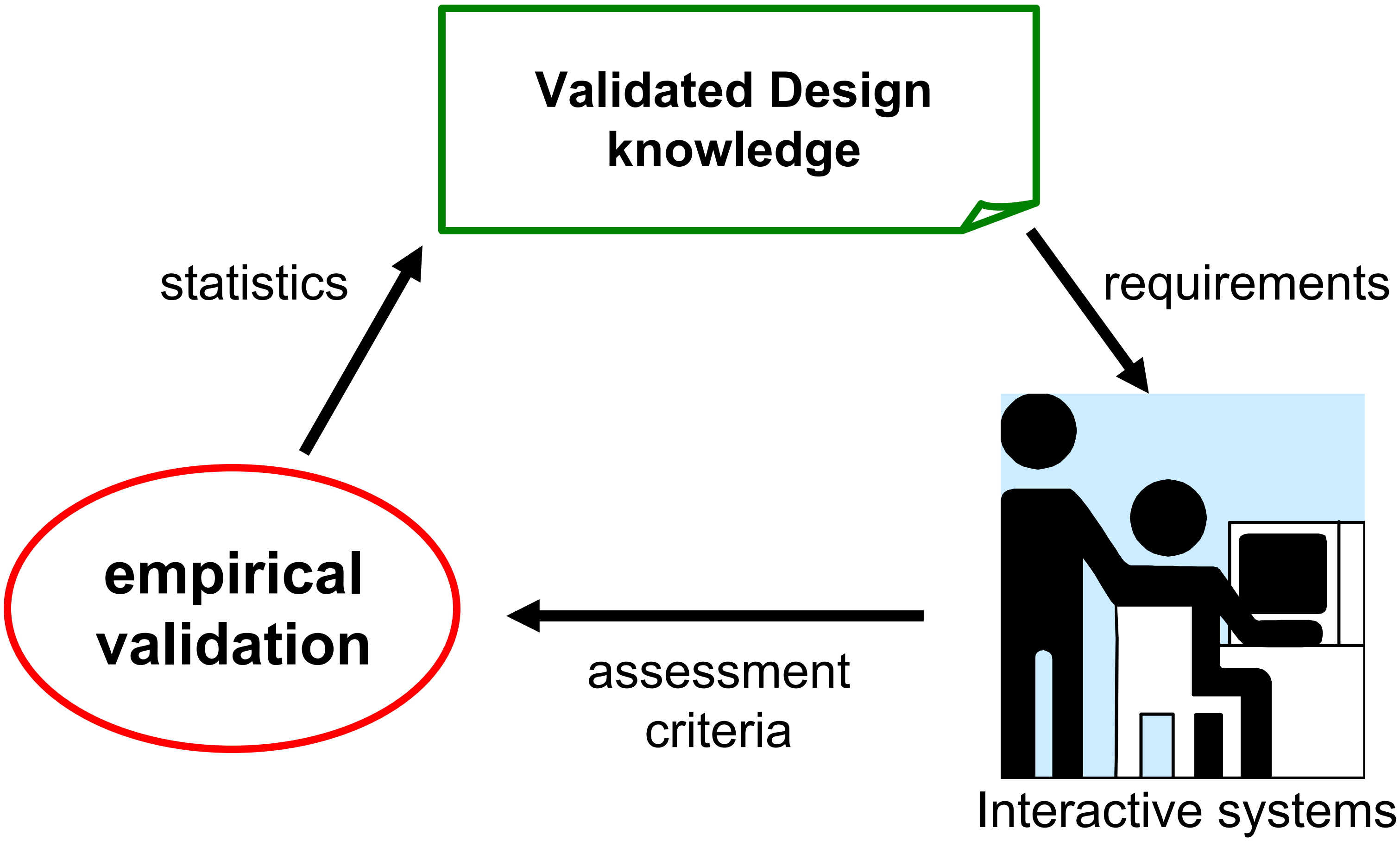
2003

Our Research Approach

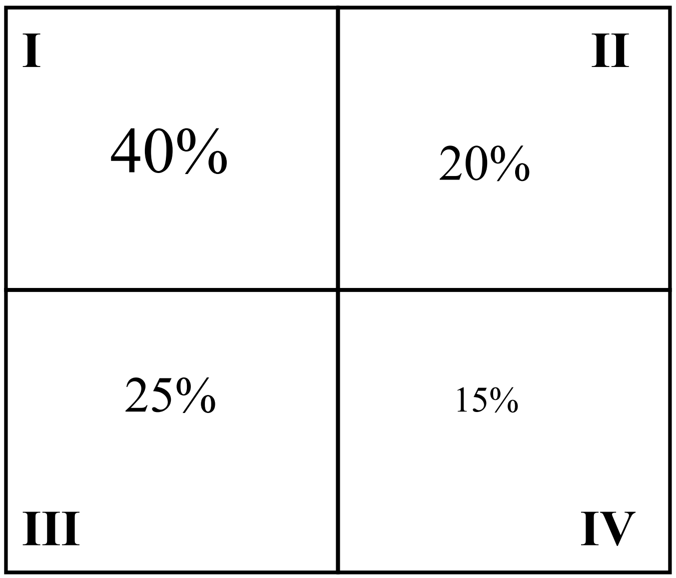


Ref: Rauterberg, M. (2000). How to characterize a research line for user-system interaction. *IPO Annual Progress Report,* no. 35, pp. 66-86.

User’s visual Attention Focus

Ref: Erke, H (1975) Psychologische Grundlagen der visuellen Kommunikation. Universitaet Braunschweig.

The relative ratios of the user's visual focus looking expectantly on one of the four quadrants of a dark and unstructured computer screen.



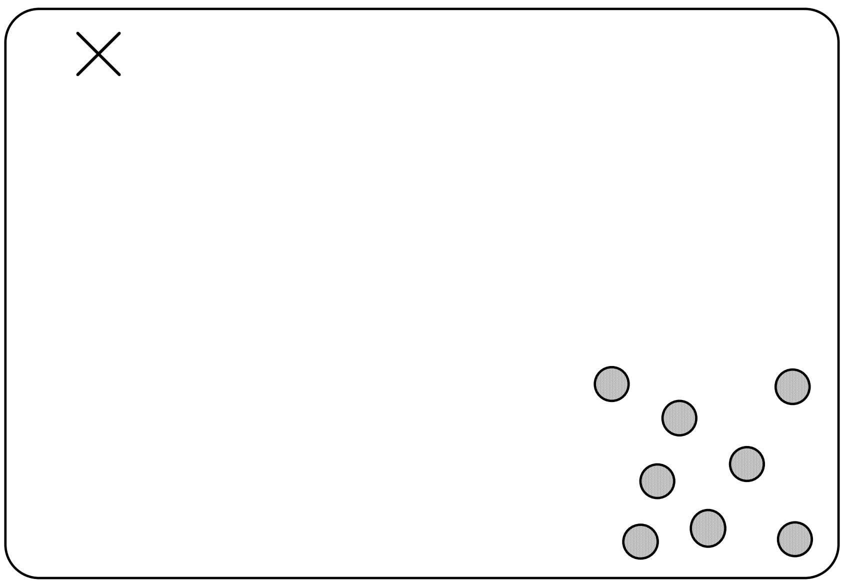
MSc Thesis (1993) from Christian Cachin

Ref: Rauterberg, M. & Cachin, C. (1993). Locating the primary attention focus of the user. *Lecture Notes in Computer Science*, vol. 733, pp. 129-140.

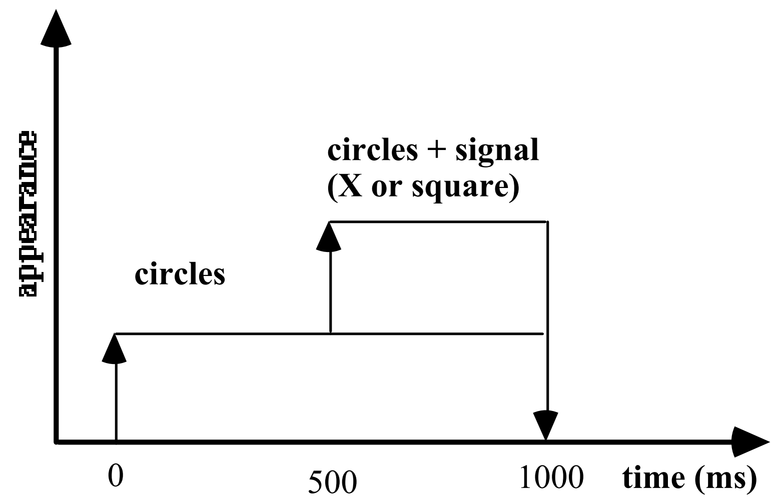
Signal Detection Experiment

N = 19; 11 women and 8 men took part in the experiment (mean age: 33 ± 14 years). 12 subjects were students of computer science at the ETH.

Dual task approach: (1) count circles, (2) detect signal X (given a distractor [])



Standard computer display: 14 inch, black&white



Results: primary task

‘Circle Deviation’ CD as a measure for task accuracy:

$$CD = |\#CIRCLES_{\mathbf{counted}} - \#CIRCLES_{\mathbf{presented}}| * 100\% / \#CIRCLES_{\mathbf{presented}}$$

I CD=6.1%	**II** CD=6.8%
CD=6.9% **III**	CD = 4.4% **IV**

Main Results:

Quadrant IV outperforms all others

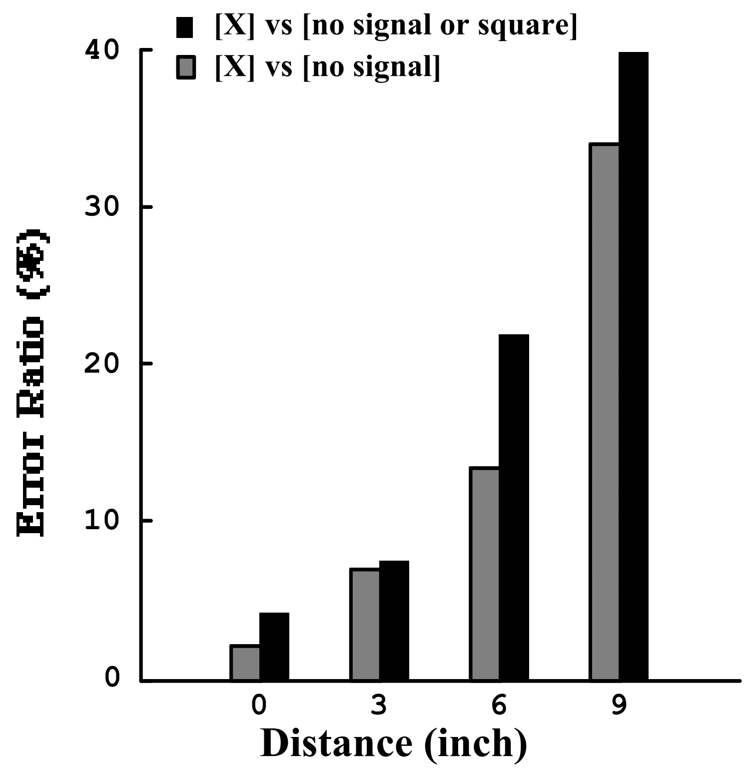
Results: secondary task

Signal Detection Table:

		NO X SIGN (nothing or square)	X SIGN PRESENTED
answer of the subject	NO	a	b
	YES	c	d

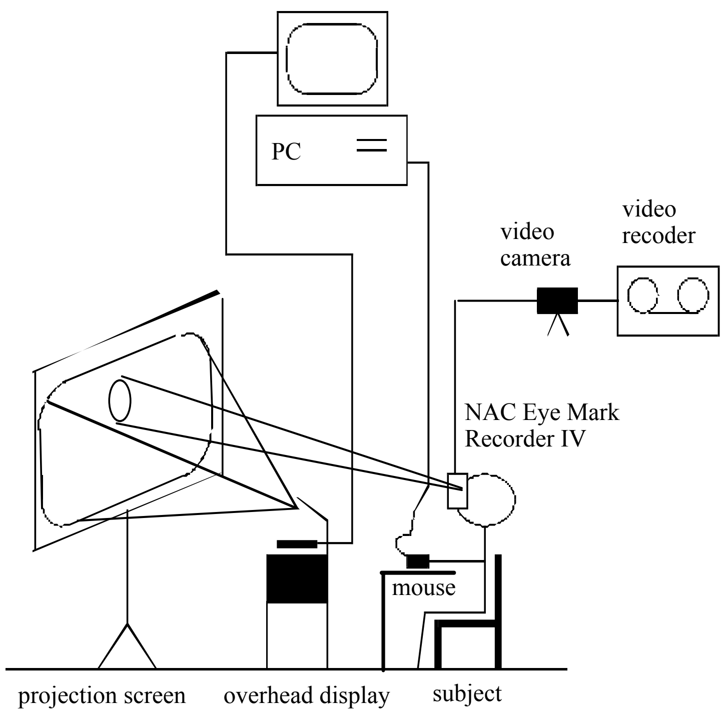
‘Error Ratio’ ER:

ER = (b + c) / (a + d) * 100%



Eye Recording Experiment

How to determine automatically the actual position of the user's visual attention focus on a computer screen?



Subjects:
N=6: 2 women and 4 men
5 subjects were students of computer science at the ETH. 1 subject studied psychology at Uni Zurich.

Tasks:
(1) Computer game;
(2) Text formatting;
(3) Hypertext navigation.

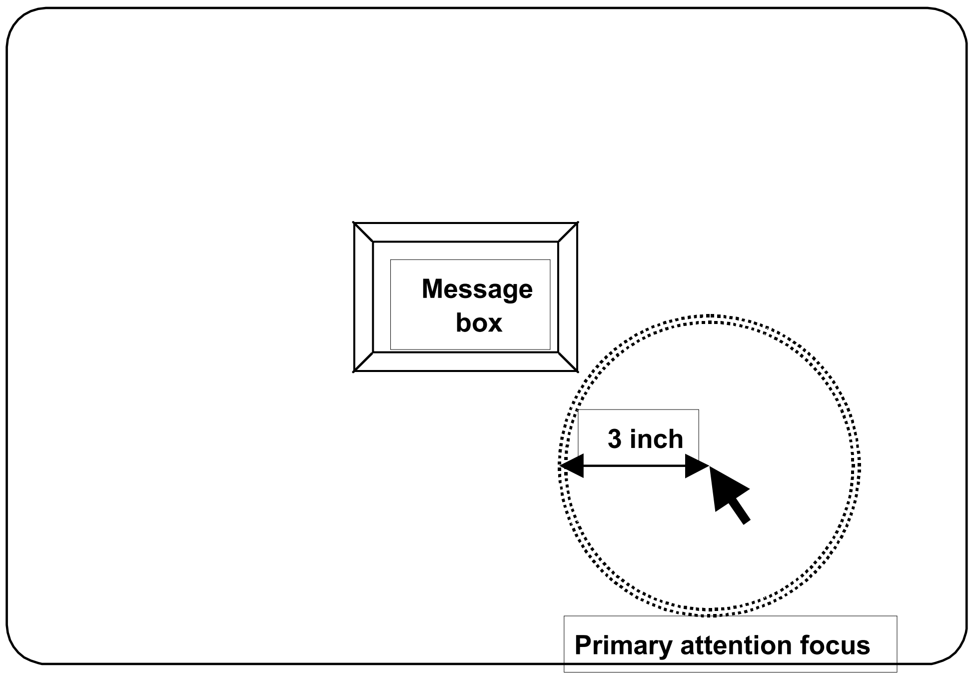
Main Results:
(1) without mouse operations:
Mouse position in fixation region for **25% - 70%**

(2) with mouse operations:
Mouse position in fixation region for **49% - 97%**

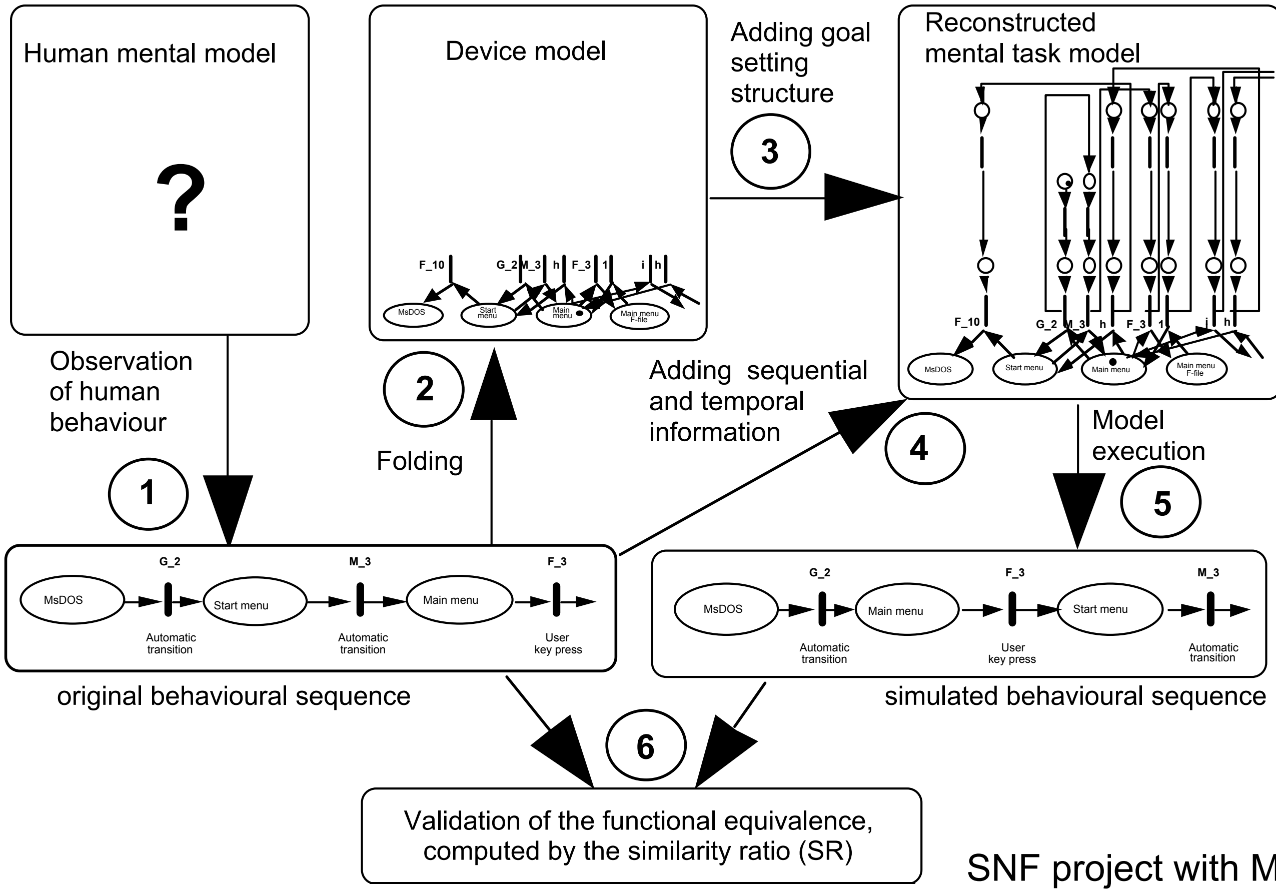
[**fixation region**: circle around fixation point with r=3 inch]

Validated Design Recommendations

(1) Place the message left above the actual user's focus of attention;
(2) Place this message maximal 3 inch away of actual mouse position.



Automatic Mental Model Evaluation



(1) Data logging
(2) Automatic Folding
(3) Add goals
(4) Add temporals
(5) Model execution
(6) Validation

SNF project with Morten Fjeld

Ref: Rauterberg, M. & Fjeld, M. (1998). Task analysis in Human-Computer interaction - supporting action regulation theory by simulation. *Zeitschrift für Arbeitswissenschaft*, vol. 3/98, pp. 152-161.

Net Complexity Metrics

Stevens, Myers and Constantine (1974):

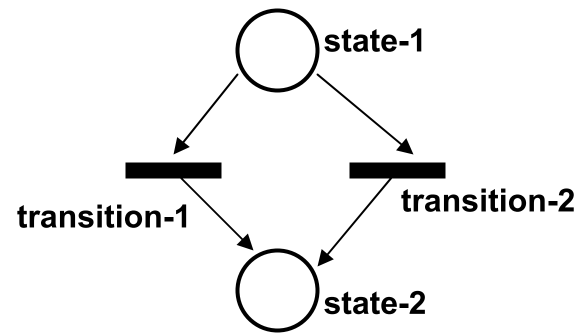
Cstate = S

Cfan = T / S

McCabe (1976): Ccycle = T - S + P [with P=1]

Kornwachs (1987): Cdensity = T / (S*(S-1))

Simple Petri Net:



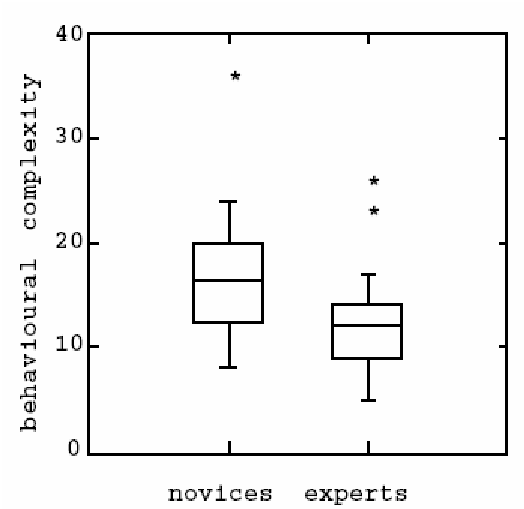
Validation study:

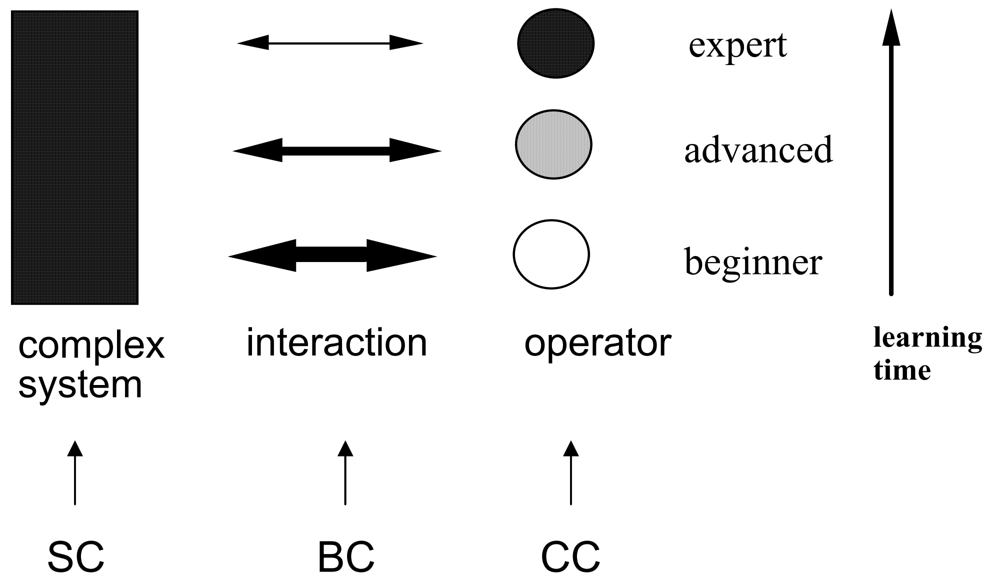
Ccycle from McCabe outperforms all other metrics!

T = number of transitions
S = number of states

Ref: Rauterberg, M. (1992). A method of a quantitative measurement of cognitive complexity. In: G. van der Veer, M. Tauber, S. Bagnara & M. Antalovits (eds.), Human-Computer Interaction: Tasks and Organisation--ECCE'92 (pp. 295-307). Roma: CUD.

Results





Experiment:

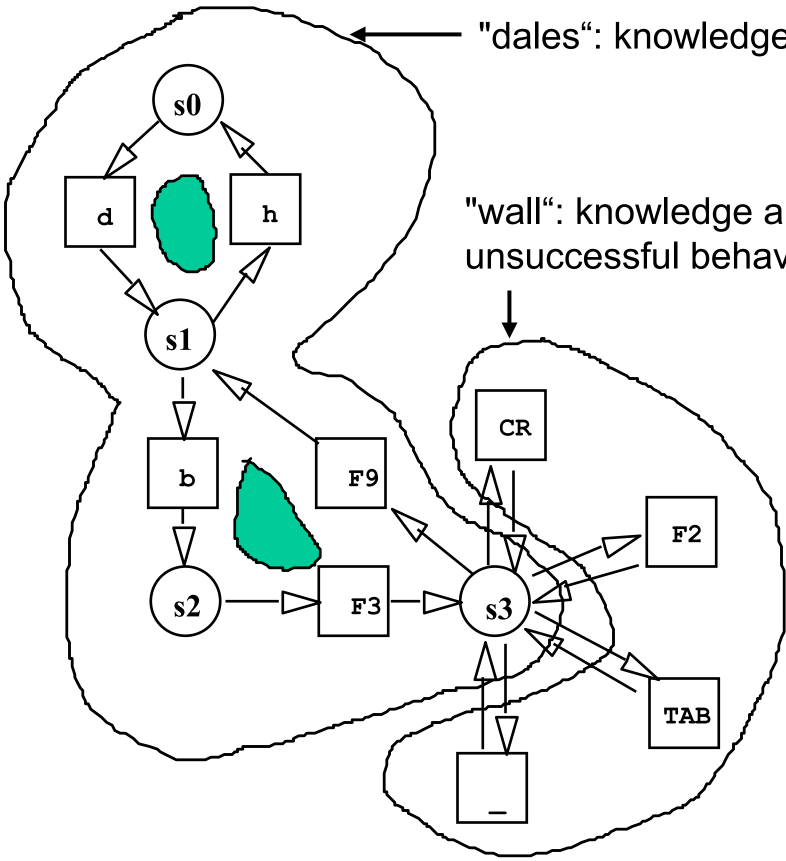
N=6 novices; N=6 experts
4 tasks with a database

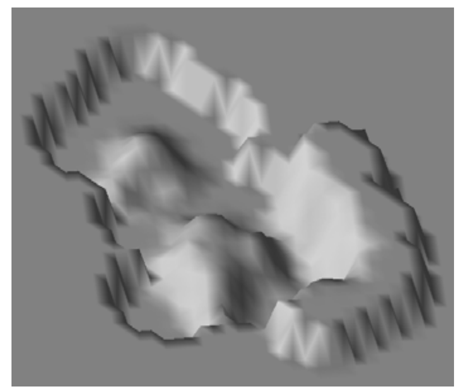
Metric BC=C**cycle**

We found a **negative** correlation between
Behavior-Complexity BC and [assumed] Cognitive-Complexity CC

Ref: Rauterberg, M. (1993). AMME: an Automatic Mental Model Evaluation to analyze user behaviour traced in a finite, discrete state space. *Ergonomics,* vol. 36(11), pp. 1369-1380.

Possible Conclusion





This conclusion would have major impact e.g. on training procedures of operators of complex systems!

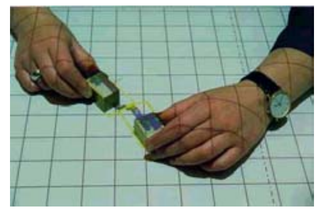
Ref: Rauterberg, M. (1996). About faults, errors, and other dangerous things. In: C. Ntuen & E. Park (eds.), Human Interaction with Complex Systems: Conceptual Principles and Design Practice (pp. 291-305). Norwell: Kluwer.

Tangible User Interfaces…

The Build-It System

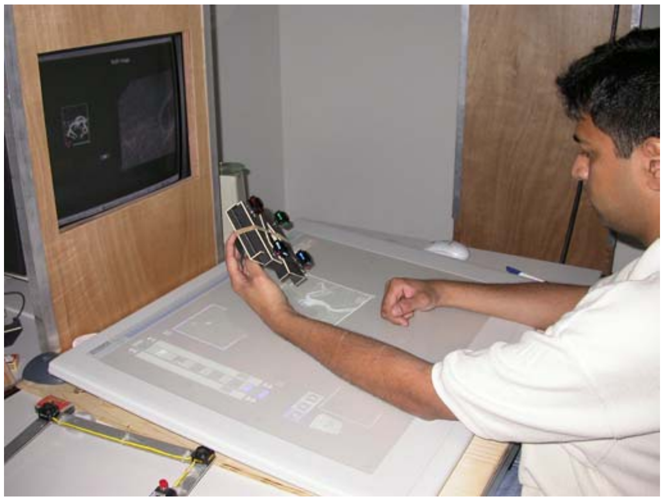
Ref: Fjeld M. , K. Lauche, M. Bichsel, F. Voorhorst, H. Krueger & M. Rauterberg (2002). Physical and Virtual Tools: Activity Theory Applied to the Design of Groupware. *Computer Supported Cooperative Work,* vol. 11(1-2), 153-180.

2D interaction:

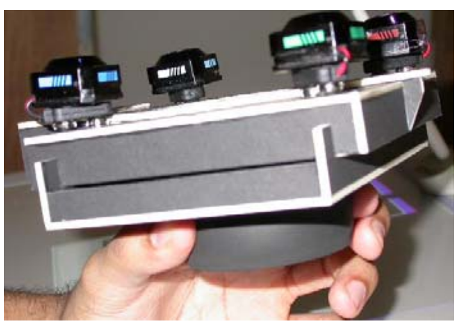


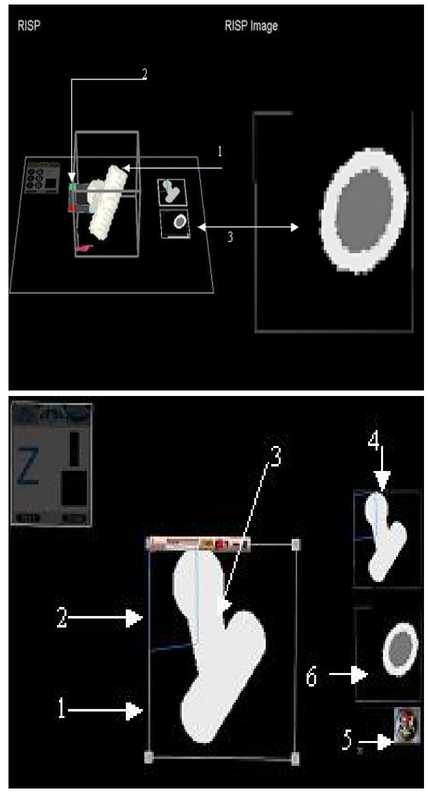
3D interaction:

3D Interaction Props

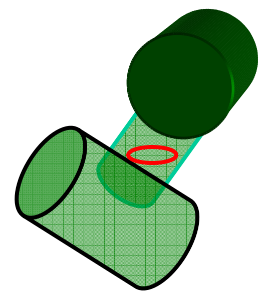


RISP:
Rigid
Intersection
Selection
Prop





Task :
locate disk (with variable diameter and thickness) in neck of phantom aneurysm and align RISP over it.



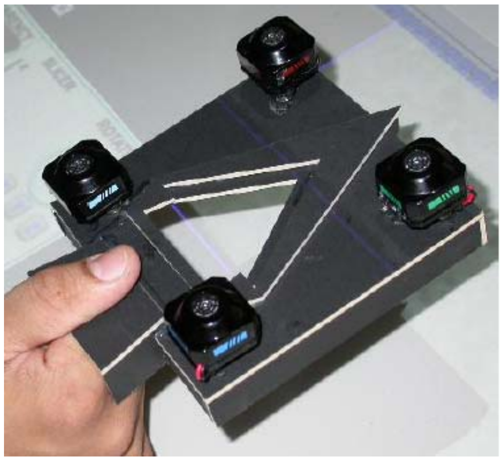
PhD Thesis (2004) from Sriram Subramanian

Different RISP designs

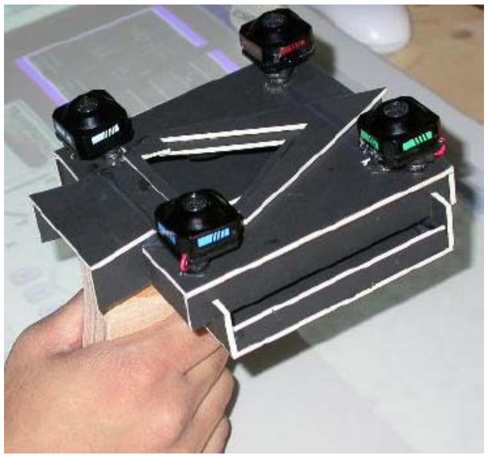
Ref: Napier, J. R. (1956). The prehensile movements of the human hand. *Journal of Bone and Joint Surgery*, vol. 38B(4), 902–913.

Napier (1956) classified grips into 2 different categories **’precision grip’** and **’power grip’**.

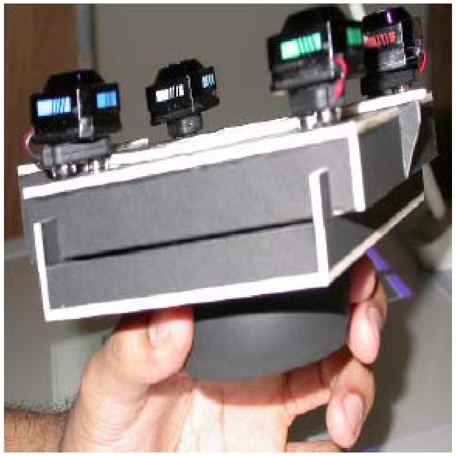
RISP Thumb



RISP Power



RISP Round



Assessment via Coordination Measures

[Ergonomics]
When using a physical 2D and 3D input device the user should produce well-coordinated movements.

[Medicine]
Surgical success depends on the controlled and orchestrated use of the appropriate instrument.

How to assess the ergonomic quality of different input devices?

Existing Measures-1

Ref-1: Fischer, A., & Kondraske, G. (1997). A new approach to human motion quality measurement. IEEE Engineering in Medicine and Biology (pp. 1701 – 1704). IEEE Press.

Multiplicative combination of 4 Dimensions of Performance (**DOP**)
(1) speed, (2) smoothness, (3) volume appropriateness and (4) accuracy.

$$speed = \frac{distance}{time}$$

$$smoothness = \frac{1}{|jerk_x| \times |jerk_y| \times |jerk_z|}$$

$$jerk_x = \frac{((X_2 - X_1) - (X_1 - X_0)) - ((X_3 - X_2) - (X_2 - X_1))}{\Delta t^3}$$

$$Volume\_appropriateness = RA_x \times RA_y \times RA_z$$

$$RA_x = \frac{1}{|appropriate\_range_x - measured\_range\_used_x|}$$

Empirical validation with clinical experts showed:

Smoothness: lowest correlation

Speed x Accuracy: highest correlation

$$Accuracy = average_{over\ j}(\frac{1}{error_j})$$

$$error_{targ\ j} = min_{over\ i}(\sqrt{(x_i - x_{targ\ j})^2 + (y_i - y_{targ\ j})^2 + (z_i - z_{targ\ j})^2})$$

TU/e

Existing Measures-2

Ref-2: Kondraske, G., & Vasta, P. J. (2000). Neuromotor channel capacity, coordination and motion quality. IEEE Engineering in Medicine and Biology (pp. 2259 – 2262). IEEE Press.

Neuro**M**otor **C**hannel **C**apacity metric
NMCC is based on Fitts' law:

$$MT = a + b \log_2\left(\frac{2A}{W}\right)$$

MT: movement time
A: target distance
W: target size

The ‘**I**ndex of **P**erformance'

IP= 1/b (in bits/sec) is used as the NMCC.

This 1D measure correlated well with known effects of age, handedness, gender, etc. on coordination drawn from a questionnaire surveying physical therapists' perception of “coordination”.
But, no explicit definition of ‘coordination’ is given.

TU/e

Existing Measures-3 and -4

Ref-3: Zhai, S., & Milgram, P. (1998). Quantifying coordination in multiple DOF movement and its application to evaluating 6 DOF input devices. In ACM Conference Proceedings on Human Factors in Computing Systems—CHI'98 (pp. 320–327). ACM Press.

Inefficiency **M**etric (IM):

$$l = \frac{Length\ of\ Actual\ path - Length\ of\ shortest\ path}{Length\ of\ Short\ path}$$

$$r = \frac{Amount\ of\ actual\ rotation - Initial\ rotation\ mismatch}{Initial\ rotation\ mismatch} = \frac{\phi_B - \phi_A}{\phi_A}$$

Ref-4: Masliah, M. R., & Milgram, P. (2000). Measuring the allocation of control in a 6 degree-of-freedom docking experiment. In ACM Conference Proceedings on Human Factors in Computing Systems—CHI'00 (pp. 25–32). ACM Press.
Masliah, M. R. (2001). Measuring the allocation of control in 6 degrees of freedom human computer interaction tasks. Unpublished doctoral dissertation, University of Toronto, Canada.

M-Metric:
m = (simultaneity of control "SOC") x (efficiency of control "EFF")

$$SOC = \int_0^T Min(NERF_1(t), NERF_2(t) \ldots NERF_n(t))dt,$$

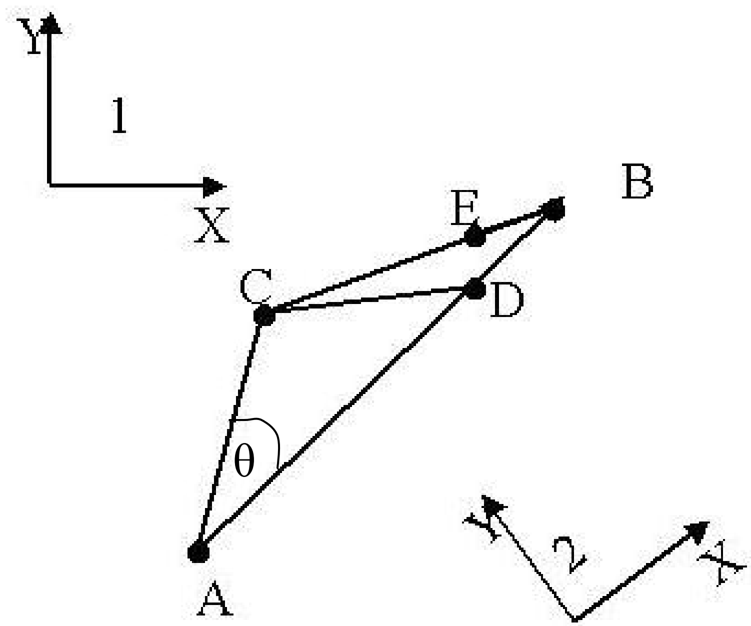
$$EFF = \sum_{i=1}^{n}(W_i \times \frac{OPT_i}{ACT_i})$$

Assessment of the different Metrics

Requirements	DOP (1997)	NMCC (2000)	IM (1998)	M-metric (2001)
(R1) trajectory based – spatial characteristic to complement time	yes	yes	yes	yes
(R2) compare the actual path with an optimal path. [The optimal path should depend on the current and target position.]	yes	**no**	**no***	**no***
(R3) independent of coordinate-system and sampling rate	yes[2]	yes	yes	**no**
(R4) applicable (or extendable) to rigid body positioning and rotation, and potentially also to scaling	**no**	**no**	yes[1]	yes[1]

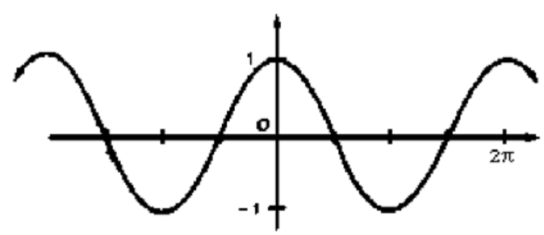
Remarks:
No* - The optimal path does not depend on the current point.
Yes[1] - No measure proposed for scaling.
Yes[2] - The smoothness and volume appropriateness measures proposed is coordinate-system dependent.

Proposed Instantaneous Coordination



If angle θ exceeds a given maximum angle θ_{max} then instantaneous coordination is 0.

COSINE of angle θ between (AC) and (AB) determines the **I**nstantaneous **C**oordination at A.



90 180

TU/e

Instantaneous Coordination C_{m-1}

Based on Binsted et al. (2001) we assume that points earlier in the path have a larger effect on perceived coordination than points closer to the target.

$$C_{m-1} = \max\left[\frac{\cos\theta_{m-1} - \cos\theta_{\max}(m)}{1 - \cos\theta_{\max}(m)}, 0\right]$$

$\theta_{\mathbf{max}}$ vary with path length:

$$\theta_{\max}(m) = \theta_1 - \theta_2 l(m)$$

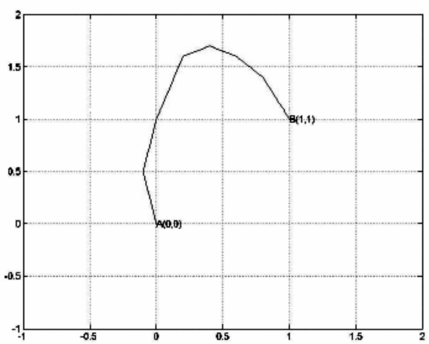
Path length: $$l(m) = \sum_{i=1}^{m} d_{i-1,i}$$

Overall Coordination
via Minkowski metric
with exponent P [0.1 < P < 1.0]

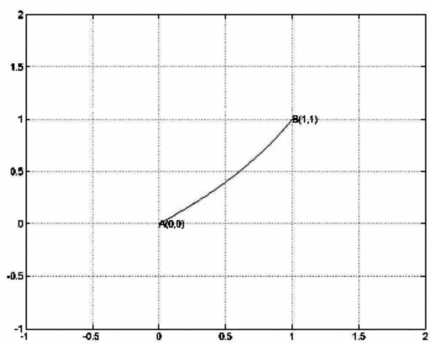
$$C = \left[\frac{\sum_m C_{m-1}{}^P d_{m-1,m}}{\sum_m d_{m-1,m}}\right]^{\frac{1}{P}}$$

Ref: Binsted, G., Chua, R., Helsen, W., & Elliot, D. (2001). Eye-Hand coordination in goal directed aiming. *Human Movement Science*. vol. 20, 563–585.

Validation experiment: 10 different user paths

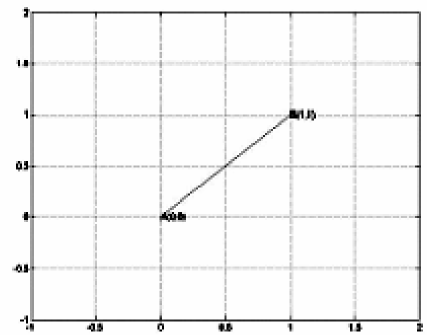


Path 1

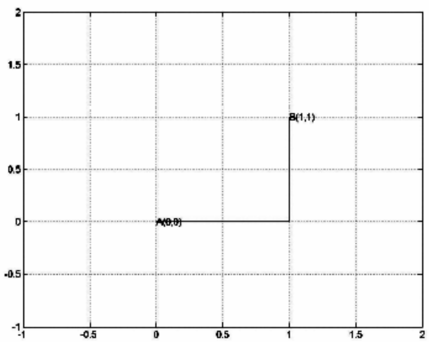


Path 2

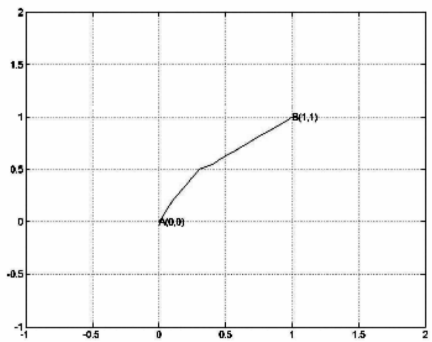
• • •



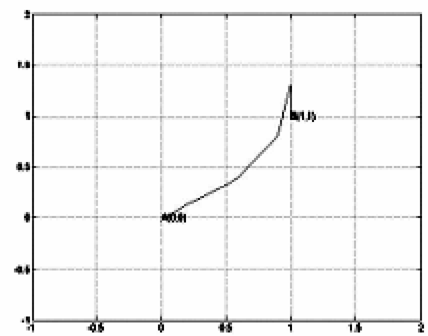
Path 7



Path 3



Path 4



Path 8

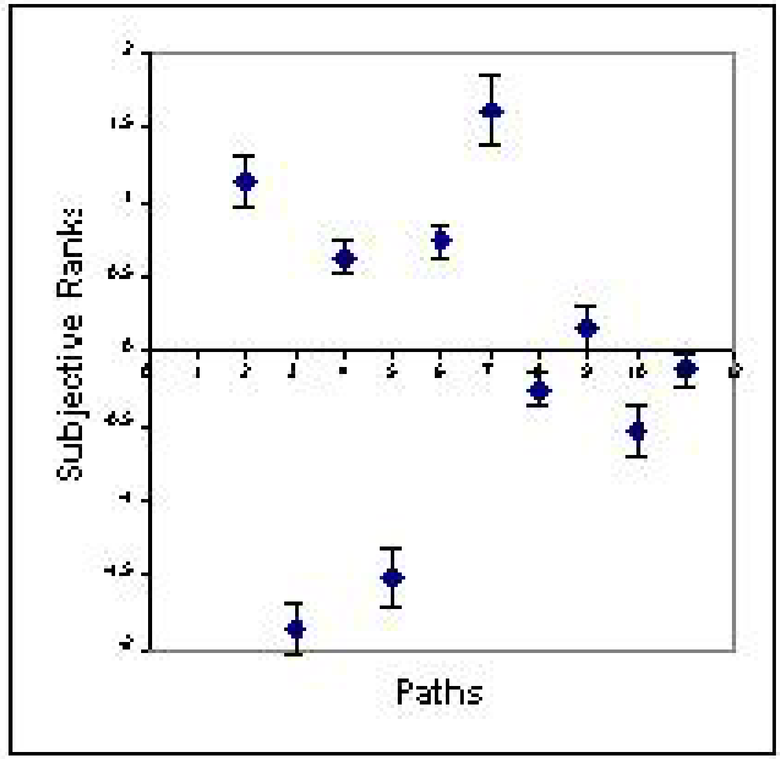
MDS Results: subjective scores

11 subjects (8 males, 3 females) were shown all 10 paths and were asked to rank them from
most coordinated (+2) to
least coordinated (-2)

Results:

Path-7 most coordinated

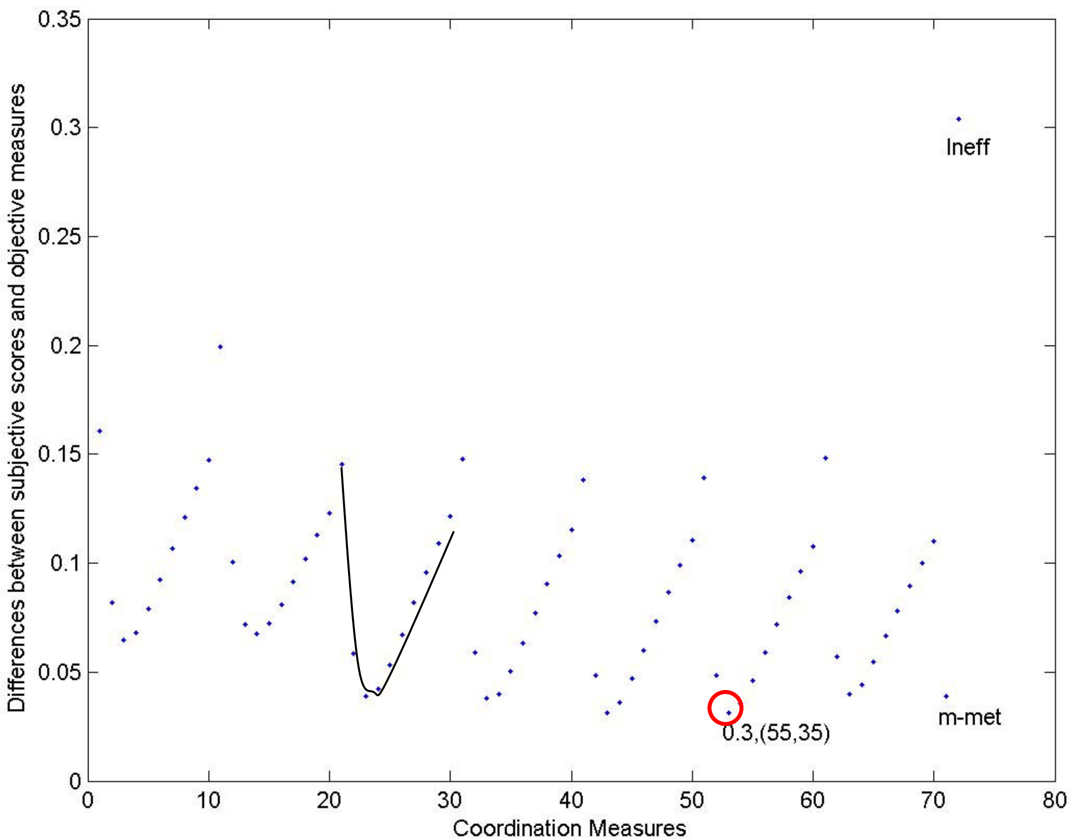
Path-3 least coordinated



Ref for MDS: Martens, J.-B. (2002). Multidimensional modeling of image quality. *Proceedings of the IEEE*, vol. 90, 133–153.

Results for overall Coordination

With varying parameters θ_1, θ_2 and P
X-axis: results of measures C, IM (Ineff), and m-Metric
Y-axis: Difference d between objective measure (X) and subjective scores (S)



(θ_1, θ_2)

(30,10)
(35,10)
(40,20)
(45,25)
(50,30)
(55,35) ← (with P=0.3; **r=0.97**)
(60,40)

exponent P:
0.1 < P < 1.0
by steps of 0.1

Differences shown as distance:

$$d = 1 - r_{xs}^2$$

$$r_{XS} = \frac{C(X,S)}{\sqrt{C(X,X)C(S,S)}}$$

$$C(X,S) = \frac{1}{n}\sum_{j=0}^{n}(X_i - \bar{X})(S_i - \bar{S})$$

Discussion

One outcome of our experiment shows that people do indeed share an intuitive understanding of the term "coordination“.

The *m*-metric has high correlation with the subjective scores, but does **not** satisfy R3: independence of coordinate system!

The computational theory for our metric C seems to accurately predict subjective impressions on coordination, and satisfies all 4 requirements!

Future Directions…

Further validation studies:

Correlations with ranking schemes based on clinical experts (patients traces and their ranks are based on the observation of the global movement path)

Correlations between performance time and other 3D task characteristics.

And how to analyze human behavior in 3D space & time over a couple of days?

Thank you for your attention.