How expertise changes perceptual processes Evidence from Eye Movement studies in reading

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* How does expertise change perceptual processes?

* Comparison: **novice – expert => extreme differences**

Novel reader (1st grade fall) vs expert reader (adult student)

 $\longrightarrow \bigcirc \longrightarrow \bigcirc \longrightarrow \bigcirc \longrightarrow \bigcirc \longrightarrow \bigcirc$

'Äiti arveli, että juusto oli homeessa' 'Mom thought, that the cheese was moldy'

Pupil, 1st grade, fall VS.



Skilled adult



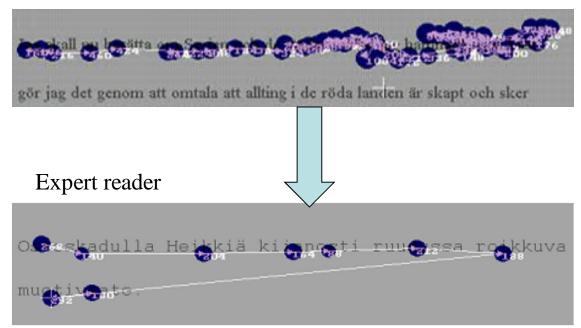
Pupil, 1st grade, fall vs. Skilled adult

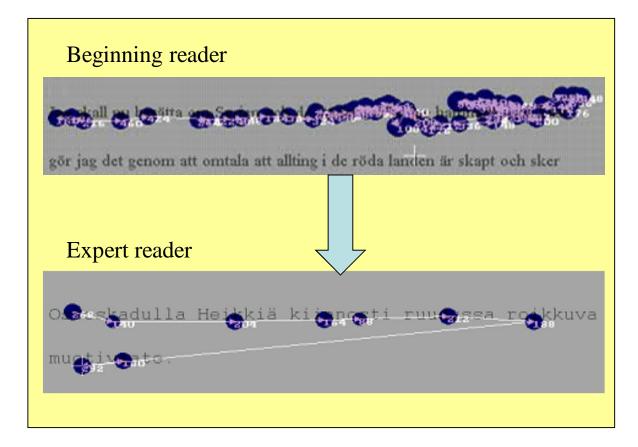


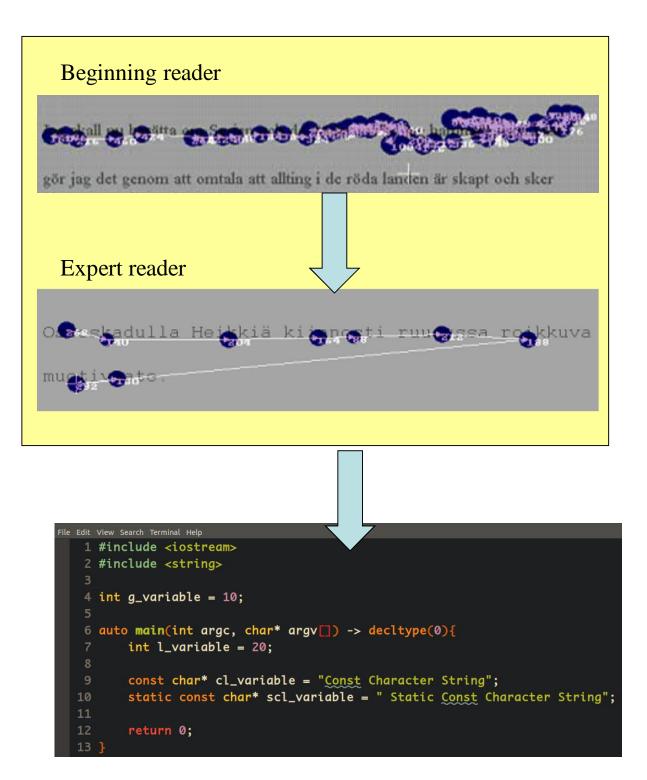
21 fixations, mean fixation duration 375 ms, 6 regressions, no skips, 7.86 seconds altogether, 1.3 s per word

4 fixations, mean fixationduration 235 ms, 1 regression,2 skips, 0.94 secondsaltogether, 150 ms per word

Beginning reader







Survey of the presentation

- **1. Use of visual cues**
- 2. Development of perceptual span => horizontal & vertical
- **3. Speed of information uptake** = foveal & parafoveal
 - The Disappearing text paradigm
 - The Boundary paradigm
- 4. Push the limits
- **5.** Some remaining issues
 - Text reading vs code reading
 - Data quality

6. Summary with suggestions for future EMIP research

All these issues discussed in context of expertise development

Visual cues are used to facilitate reading

Text Level: Headings, subheadings, whitelines, indentation, bolding, underlining

 \Rightarrow Inform you about organization of the text

Sentence level: Spaces, specific character combinations

 \Rightarrow Inform you about word boundaries

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Reading without spacing is 30% slower than reading with spaces

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Reading without spacing is 30% slower than reading with spaces Reading without spacing is 30% slower than reading with spaces (*Rayner & Pollatsek, 1996*)

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Reading without spacing is 30% slower than reading with spaces Reading without spacing is 30% slower than reading with spaces (*Rayner & Pollatsek, 1996*) Not in Japanese though (Sainio, Bingushi, Hyönä, Bertram, 2007)

Visual cues are used to facilitate reading

Word level: To denote sublexical structure

 \Rightarrow Inform you about the structure of a word

E.g., the space in English compounds: garden party E.g., the hyphen in Finnish compounds: vaihto-ohjelma 'exchange program'

Visual cues are used to facilitate reading:

Assumption is that low-proficient readers need more visual cues

成田 空港の 経営は 現状では

お世辞にも 優良とは いえない。

Japanese Children L2 Readers: used to space but not character sequence info to find word boundaries

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Japanese Children L2 Readers: used to space but not character sequence info to find word boundaries



Varis kirjoittaa kirjeen

Hei serk-ku!

Mi-tä si-nul-le kuu-luu? Mi-nul-le kuu-luu tä-nään hy-vää.

Ei·len mi·nul·le kuu·lui huo·no·a. Jäin luk·ko·jen taak·se. Ei se mi·nun syy·ni ol·lut. Jo·ku o·li jät·tä·nyt hä·kin vää·rään paik·kaan.

Finnish 1st and 2nd graders

Visual cues are used to facilitate reading:

Assumption is that low-proficient readers need more visual cues

There is evidence that supports this notion

vaihto-ohjelma ulko-ovi

Adults facilitated by hyphen when processing long but not short compounds: 2nd graders: facilitated by hyphen when processing long & short compounds

<mark>vaihto-ohjelma</mark>

ulko-ovi

Bertram & Hyönä, 2013; Häikiö, Bertram, Hyönä, 2011 **Probably need of extra visual cues not only on word level**

Use of visual cues in reading code (code comprehension, addition, debugging) Code conventions: Colors, Indentation, Capitalization



* Visual cues more important for novice/beginning coders?

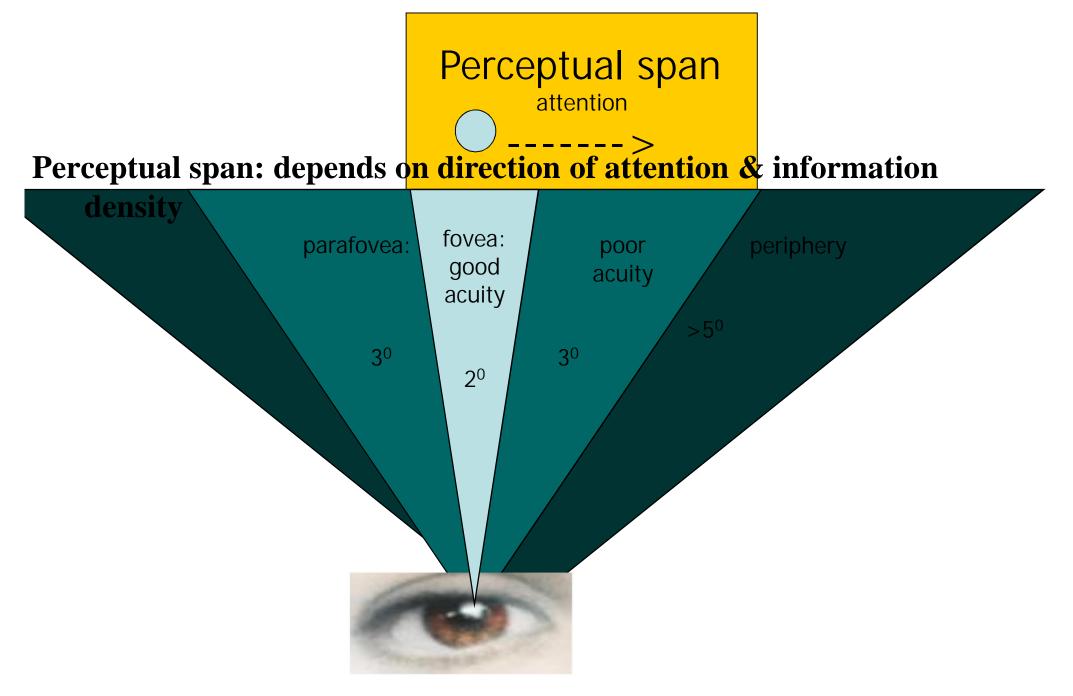
if x == 1:
 print ("x is 1")
 print ("x is odd")

Use of visual cues in reading code (code comprehension, addition, debugging) Code conventions: Colors, Indentation, Capitalization

- In general, to what extent are they used by novices vs expert ⇒EM guidance
- * Visual cues more difficult in L2 when not compatible with L1 cross-language interference? (Strong L1 Javascript – Weak L2 C++)

=> Few EM exp. in EMIP on use visual cues – expertise development => Measures affected by vc: durations, saccadic amplitude, scan paths

- Perceptual span: Area from which we extract useful information during reading
- Size of perceptual span measured by moving window paradigm



Moving window (Häikiö, Bertram, & Hyönä, 2009)

Notkea kissa oppii liikkumaan taitavasti vaikeissakin paikoissa. Suuresta, sileästä puusta kissa...

[The flexible cat learns to move skillfully even in hard places. The cat [gets down] from a large smooth tree...]

Notkea kiss cqqll illhhnwssu felfeueafl uelbslaaeblu qelhclees. Boonaefs, alisöefö qnnafs hlees...

Mcfb<u>ea kissa op</u>qll illhhnwssu felfeueafl uelbslaaeblu qelhclees. Boonaefs, alisöefö qnnafs hlees...

Mcfboe bla<mark>sa oppii li</mark>lhhnwssu felfeueafl uelbslaaeblu qelhclees. Boonaefs, alisöefö qnnafs hlees...

Mcfboe blaas cqqll liikkumaan felfeueafl uelbslaaeblu qelhclees. Boonaefs, alisöefö qnnafs hlees...

Table 3

Type of information obtained to the right of fixation in the current study and Rayner (1986)

	Second grade	Fourth grade	Sixth grade	Adults
Letter identity (current study)	5	7	9	9
Letter feature (Rayner Experiments 2 and 3)	7	11-12	11-12	11-12
Word length (Rayner Experiment 1)	11	11	14	14-15

<u>SPAN</u>

W=5 MANIPULATION

Letter identity (LI): Letter feature (LF): Word length (WL):

oppii	illhhnwssu	(liikkumaan)	– LI
oppii	xxxxxxxxxx	(liikkumaan)	-LI + LF
oppii	xxxxxxxxxxx	(liikkumaan)	- LI, LF + WL

EXCLUDE

Table 3 LI LF WL Type of information obtained to the right of fixation in the current study and Rayner (1986)

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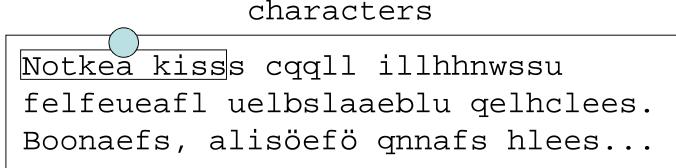
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- Growing expertise, growing span; assymptote reached after 6 years of reading experience
- Would that be the same when gaining expertise in reading code?

Window size 11





* Additional need: vertical perceptual span to capture non-linear reading

INTERNATIONAL JOURNAL OF PSYCHOLOGY, 2010, 45 (1), 40-47

Vertical perceptual span and the processing of visual signals in reading

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University of Turku, Turku, Finland



Normal Condition

EDOBLIDGES D'AMERICAL ET ROLETIONS

bepuis la revolution industrialia, los peus industrialisés sont devenus de plus en plus expendente en la production d'ésargue pour menténic leur économie et leur alvens de van. Les pourme erientes e d'ésargue cont le précleme de familie, leur convent et depuis peus le confidence. Non pourme à primeires d'ésargue des préclemes gennes trèse per convent, et depuis peus le confidence. Non pourme à primeires de des préclemes gennes trèse per convent, et depuis peus le confidence, et get mettrei et au multime.

I. PROBLEMENT C'ANDROLD

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A. Des responseen de combastibles en diminstion

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1. Des méthodes de priduction desgeceuses

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i. Des solls de plus en plus élevés

Les roits de l'énergie hande est les undeustibles fonciles et le instituce en segmentation, énou ou marché concerventie, le disponsibilité décensionent de chardon, du pértie et de gen astroit met les verdeurs en position de férice. Le gian, l'encessimilité de sours en moine établente des conferentièles foncies conclis problemation d'ésemptie plan catolous, cett instant, section à le fois du poir établente à des sedemate resulte pour le forage et l'estruction, et de le secencent d'arillaner des technologies plus perfectamentes.

R. Los degits couche à l'exetencement

S'atilisatile empire des concernière fonciles et du sociéties meners notre éservenement de constructure façone. Fra consemptés juste à compredice l'étante des problèmes extransmenteux que noue aving générés. Tex-co acté multiples et probabilisatilise pour la playert.



Figure 1. Illustration of the gaze-contingent window technique used in the experiment.

- Normal condition: => More returns and time spent on (sub)headings
- Code readers: => Low expertise: Linear reading => small windows sufficient

Window Condition



3. Speed of information processing: foveal

- Speed information uptake foveal area: **disappearing text paradigm**
- Adults have no cost when fixated word disappears after 60ms (Rayner et al., 2003; Liversedge et al., 2004).

* 60ms: Sam wore the horrid though his prett	
60ms: Sam wore the horrid though his prett	
.	ty girlfriend complained.

Sentence RT	Normal	Disappearing	No Difference
Ν	3286	3327	<i>t</i> s < 1

- Different with 8-9 year olds reading longer words e.g., sairaala (Blythe, Häikiö, Bertram, Liversedge, Hyönä, 2011)
- \Rightarrow Can be used as a way to measure expertise, also in code reading

3. Speed of information processing: parafoveal

- Cost when parafoveal word disappears after 60ms => underlines importance of parafoveal word in reading (Rayner, Liversedge, & White., 2005).
- 0 ms: Sam wore the horrid coat though his pretty girlfriend complained.
- 60ms: Sam wore the horrid coat his pretty girlfriend complained.

Sentence RT	Normal	Disappearing	Difference
N+1	3449	4045	<i>p</i> < .05

- Different with children making less use of parafoveal info?
- \Rightarrow Can be used as a way to measure expertise, also in code reading
- \Rightarrow Also boundary paradigm used to assess nohana of parafov. proc.

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3. Speed of information processing: parafoveal

- Research demonstrates that parafoveal processing is critical for normal efficient reading.
- Parafoveal preview benefit
- How important is parafoveal processing for reading code?
- Disappearing code paradigm, or code boundary paradigm
- Also these paradigms could be vertically orientated
- Development in parafoveal processing \(Comparison Gaining expertise)

4. Push the limits

• Finnish L2 speakers processing short high-frequency words (auto, posti)

 \Rightarrow no insight in level of expertise

• Real challenge => Morphophonological variation

consonant gradation (p, k, t):

ka t u =>	ka d ulla 'on the street'
il t a =>	illalla 'evening' => 'in the evening'
tau k o =>	tauolla 'in the break'

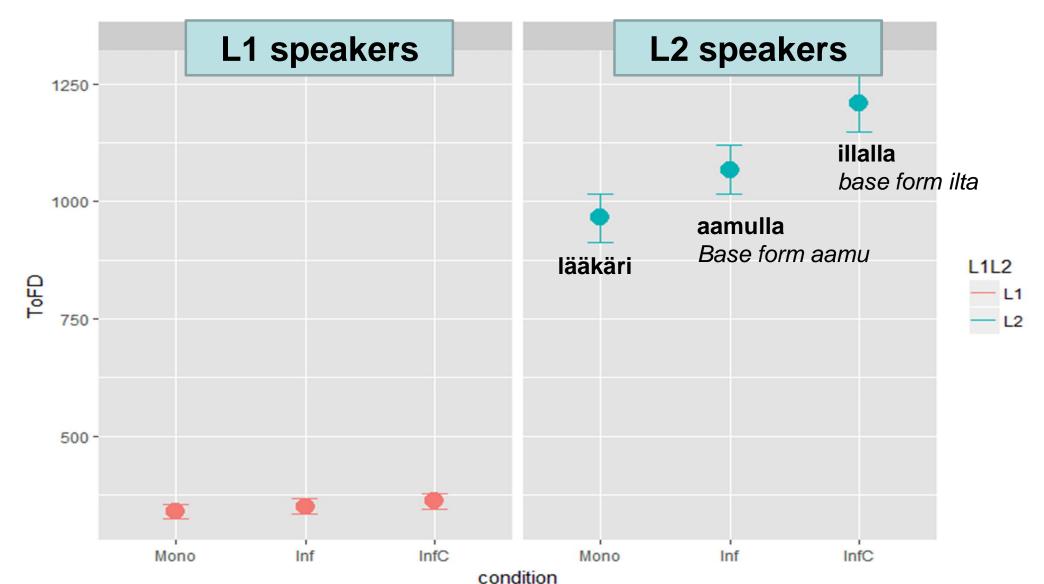
- But katu => katua 'street (ptv) katu => katuna 'as a street'
- keitin => keittimellä 'with the cooker' (4 morphophon. rules in one inflection)

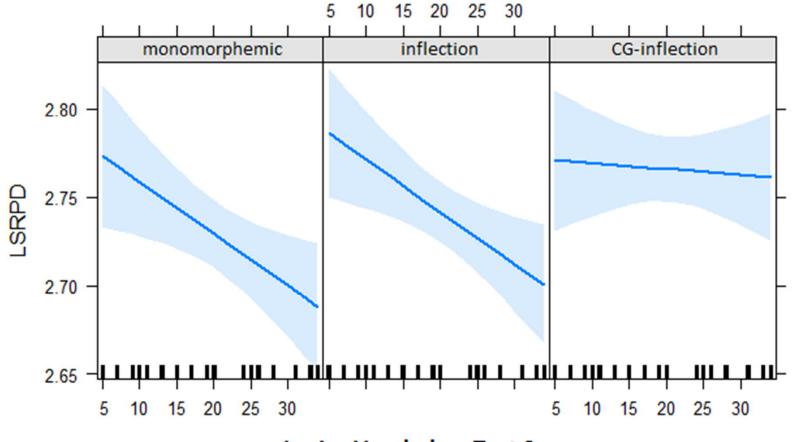
ystävyys, ystävyyden, ystävyyttä, ystävyytiin, ystävyyksien

• L2-speakers disproportionate problems with Consonant Gradation (Salmela, Bertram, Lehtonen, & Vainio, submitted).

Mono: Koska lääkäri oli neuvonut minua lepäämään, päätin jäädä kotiin. Inf: Koska aamulla oli pilvistä, otin mukaani sateenvarjon. - aamu InfC: Koska illalla oli huono ilma, en mennyt ulos – ilta (CG)

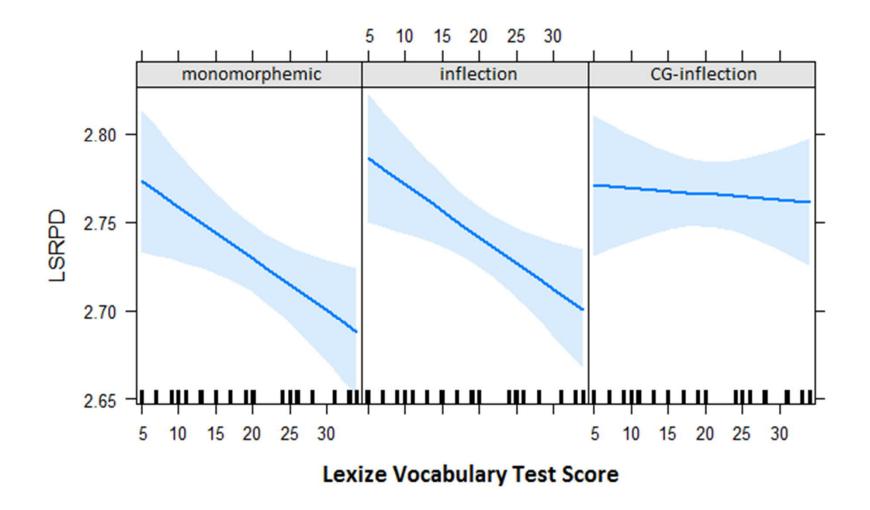
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Lexize Vocabulary Test Score

4. Push the limits



=> Don't use too easy code snippets when trying to assess EM-patterns related to expertise

5. Text vs Code Reading: Some Remaining issues

a. Comparing text reading with code reading

- What drives EM behavior?
- Text Reading: word length, frequency, predictability directly related to EM measures (durations, saccadic amplitude, skips, regressions).
- These factors have been assessed wrt expertise development as well (e.g., effect of WL decreases with age).
- Code Reading: Factors that may be linked to EM measures: Place in hierarchy, degree of repetition, relevance, line length, visual cues ⇒ systematic investigations
- Interaction of expertise and these factors?

5. Text vs Code Reading: Some Remaining issues

b. Data quality: 5 experts vs 12 novices (also in text reading studies)

Collaborative research efforts => Next to cross-laboratory and crosslinguistic studies, development of Eye-tracking corpora for reading:

- English (Frank et al., 2013; Luke & Christianson, 2018)
- German (Kliegl et al., 2006)
- Hindi (Husain et al., 2014)
- Russian (Laurinavichyute et al., 2019).
- English-French (Pynte & Kennedy, 2006; Whitford & Titone, 2012)
- English-Dutch: GECO (Cop et al., 2017)
- MECO (Siegelman, Kuperman et al., in prepartion): Multilingual eye movement corpus <u>https://meco-read.com/</u>

English, Dutch, Finnish, German, Hebrew, Spanish, Turkish, Russian, Italian, Norvegian, Greek, Korean as L1 & all of these for English as L2

5. Summary & suggestions for future EMIP research





1. Visual cues heavily used on word, sentence and text level

- \Rightarrow Segmentation into smaller units, text organisation
- \Rightarrow Language proficiency related to usefulness of visual cues
- \Rightarrow Code: visual cue exploitment related to expertise?

2. Perceptual span grows with development, levels off at grade 6

- \Rightarrow Developmental pattern in code reading
- \Rightarrow worth considering to investigate vertical span

3. Parafoveal processing crucial for fluent reading.

- \Rightarrow Information extraction of upcoming word affords fast reading rate
- ⇒Code disappearing and code boundary paradigm to assess development of parafoveal processing in code reading
- \Rightarrow Possibly also in vertical direction

5. Summary & suggestions for future EMIP research





4. Large-scale corpora or cross-linguistic enterprises

- \Rightarrow plenty of subjects to enhance data quality
- ⇒ background questionnaires and tests that can be linked to expertise development (e.g., **memory span**)

5. Direct comparison between text reading & code reading

- ⇒ Factors that predict eye movement behavior in reading known, in coding less established.
- \Rightarrow Interaction of factors with expertise
- ⇒Expertise may play out in certain measures (e.g., scan path) but not in others (e.g., dwell time, saccadic amplitude)

KIITOS

&

HAVE A GOOD CONFERENCE!