Towards understanding differences between reading on paper and screen: measuring changes in brain activity

(findings from pilot research in *Cyprus Interaction Lab*)

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Previous researches

- Differences in presentation format have a significant effect on fixation duration, number of fixations per minute, and number of regressions (Sharmin, Spakov, Raiha, 2012);
- reading behaviour on computer displays, eReaders is similar to reading from a printed book (Zambarbieri, Carniglia, 2012);
- readers perceive more positive than negative affordances regarding reading on paper, while reading on screen attracts fewer virtues (Taipale, 2014)
- when compared reading from a desktop computer monitor with an equivalent hard copy printed text, blink rates were not reduced during computer operation (Chu, Rosenfield, Portello, 2014);
- experiment on symptoms (ocular discomfort) following sustained computer use showed significantly worse results than those reported after hard copy fixation under similar viewing conditions (Chu at all, 2011);
- etc.

Research questions

- Can cheap and easy to use brainwaves measuring devices be used for exploring reading processes by measuring activities such as attention (concentration) and meditation (relaxation)?

- Is reading medium (paper, different type and size screens) affect the level of attention?

MindSet with NeuroSky ThinkGear™ technology

Starting at $80 (2015)

- The patterns and frequencies of electrical signals emitted by neurons firing in the brain (commonly referred to as brainwaves) are measured by placing a sensor on the scalp.
- Brainwaves are processed into digital signals to make the measurements available to games, applications and further analysis.
- Both the raw brainwaves and the **eSense Meters (Attention and Meditation)** are calculated.

eSense Meters (Attention and Meditation)

- eSense Meters is an algorithm for characterizing mental states.
- Technology amplifies the raw brainwave signal (electroencephalography (EEG) components) and removes the ambient noise and muscle movement.
- Algorithm is then applied to the remaining signal, resulting in the interpreted eSense meter values.
- eSense meter values do not describe an exact number, but instead **describe ranges of activity (1–100)**.
- eSense meters are a way to show how effectively the user is engaging Attention (similar to concentration) or Meditation (similar to relaxation).

eSense scale

- Values from 80 to 100 are considered “elevated”,
- values from 60 to 80 is considered “slightly elevated”,
- values between 40 to 60 is considered “neutral”,
- values between 20 to 40 indicates “reduced”,
- value between 1 to 20 indicates “strongly lowered” levels of the eSense.

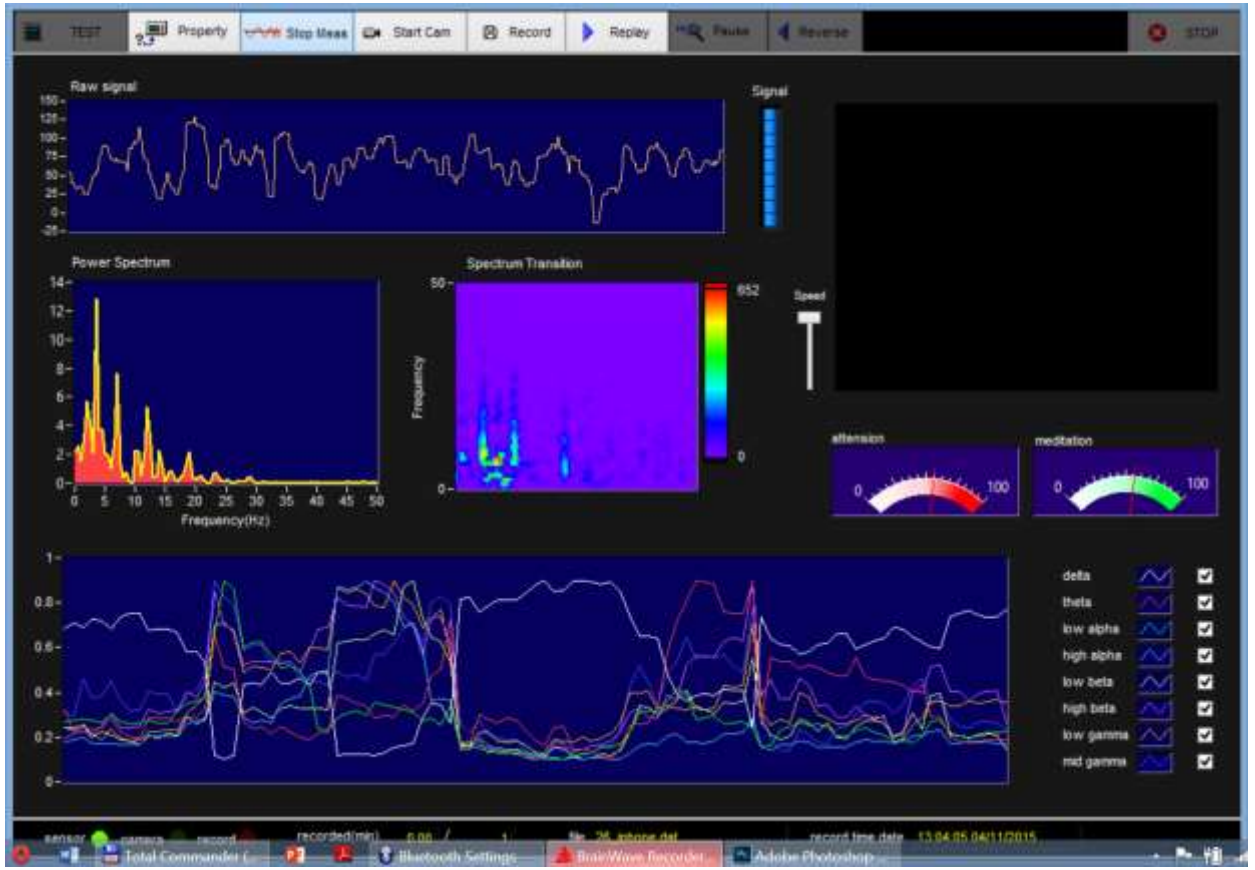
Attention eSense

- Attention meter indicates the intensity of a user's level of mental “focus” or “attention”.
- Occurs during intense concentration and directed (but stable) mental activity.
- Value ranges from 1 to 100.
- Distractions, wandering thoughts, lack of focus, or anxiety may lower the Attention meter level.

Brainwave Visualizer software

- interactive application controlled by brain,
- shows a graphical representation of brain's activity,
- includes the Brainwave Visualization, Brainwave Power Spectrum Graph, and the eSense Attention and Meditation meters.

MindRecord software



- Shows electroencephalography (EEG) components, such as delta, theta, alpha, etc, and **attention, meditation** data in real time.
- Converts data to CSV format.
- Price $200.

http://store.neurosky.com/products/mindrec-trial-version
http://store.neurosky.com/products/mindrec

Experiment

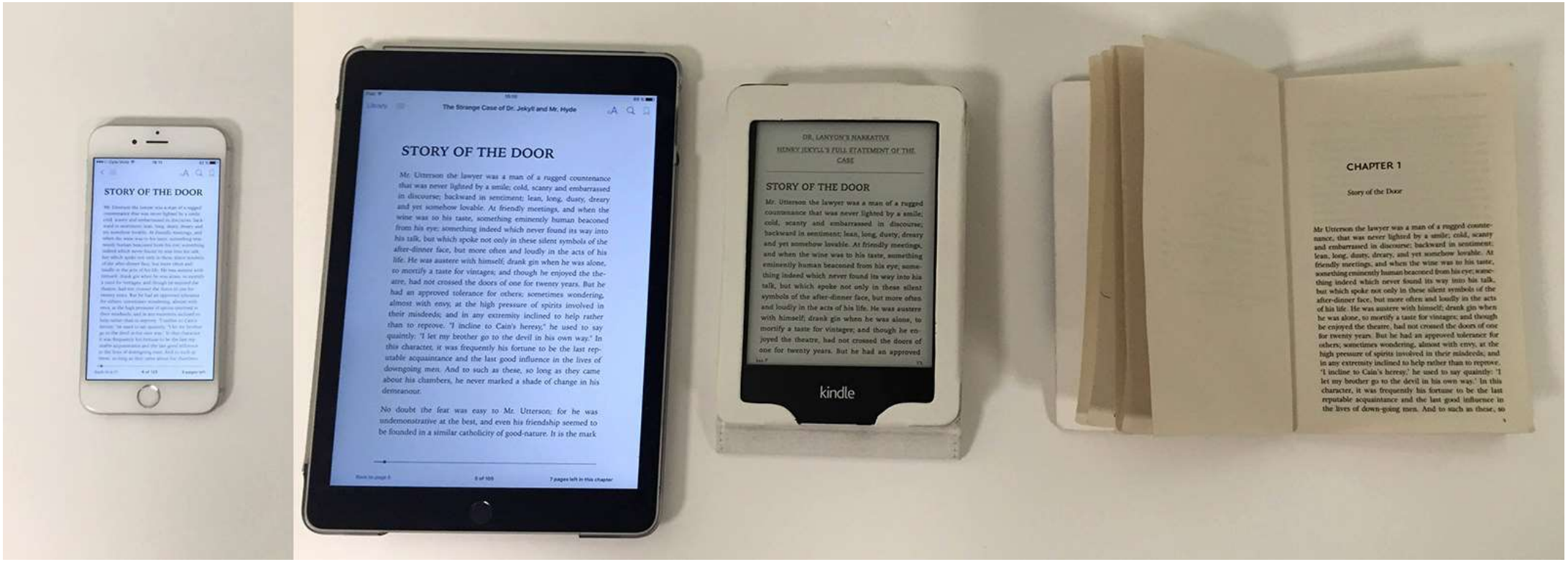
First stage:

- 6 respondents reading 2 books in English for 5 minutes with each device (iPad, iPhone, Kindle, Printed). Total reading time: 240 min.

Second stage:

- 1 respondent reading 2 books in English and 2 books in Lithuanian (mother tongue language) for 10 minutes with each device (iPad, iPhone, Kindle, Printed). Total reading time: 160 min.

Reading devices



- **Printed book** (soft cover, pocket size)
- LARGE SCREEN: **iPad Air 2** (9.7-inch, 2048x1536 pixel resolution at 264 ppi, LED-backlit with IPS technology)
- MIDDLE SIZE SCREEN: **Kindle Paperwhite** (6-inch, 1334x750 pixel resolution at 212 ppi; Carta e-paper technology, 16-level gray scale)
- SMALL SCREEN: **iPhone 6** (4.7-inch, 1334x750 pixel resolution at 326 ppi, LED-backlit with IPS technology)

Books (in English and Lithuanian)

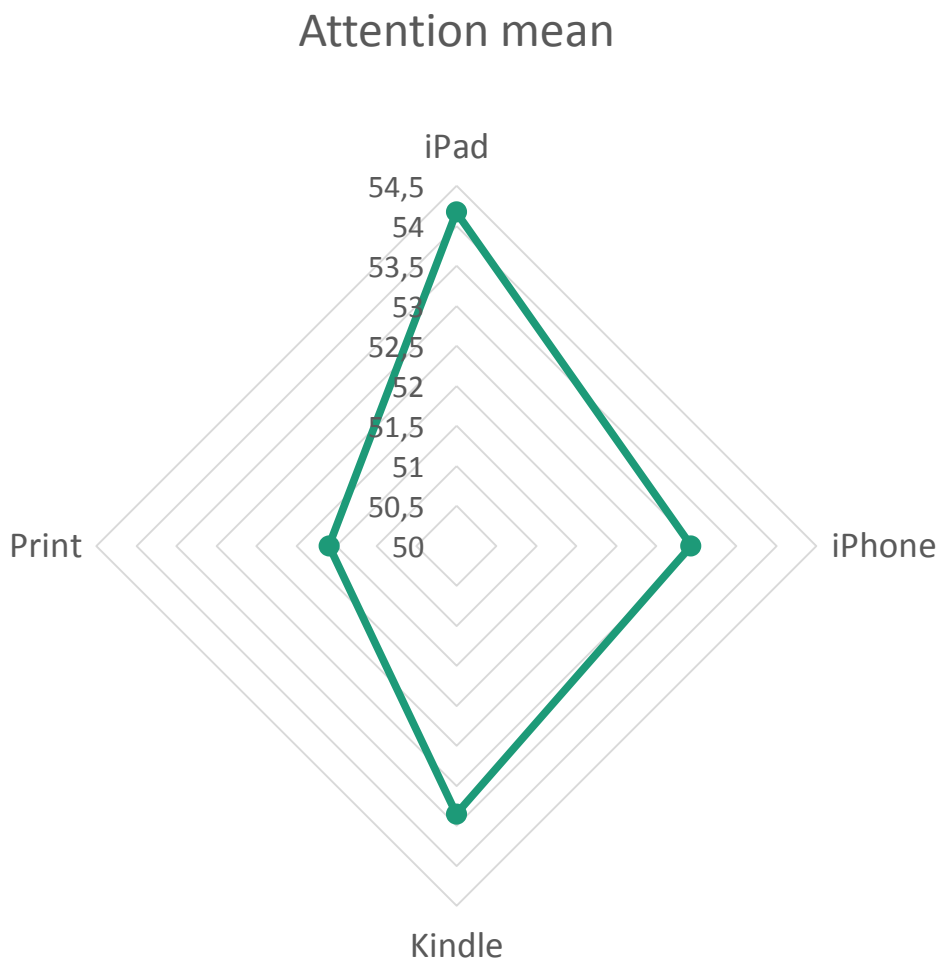
Preliminary findings

First stage

6 respondents reading 2 books in English for 5 minutes with each device (iPad, iPhone, Kindle, Printed). Total reading time: 240 min.

Attention mean

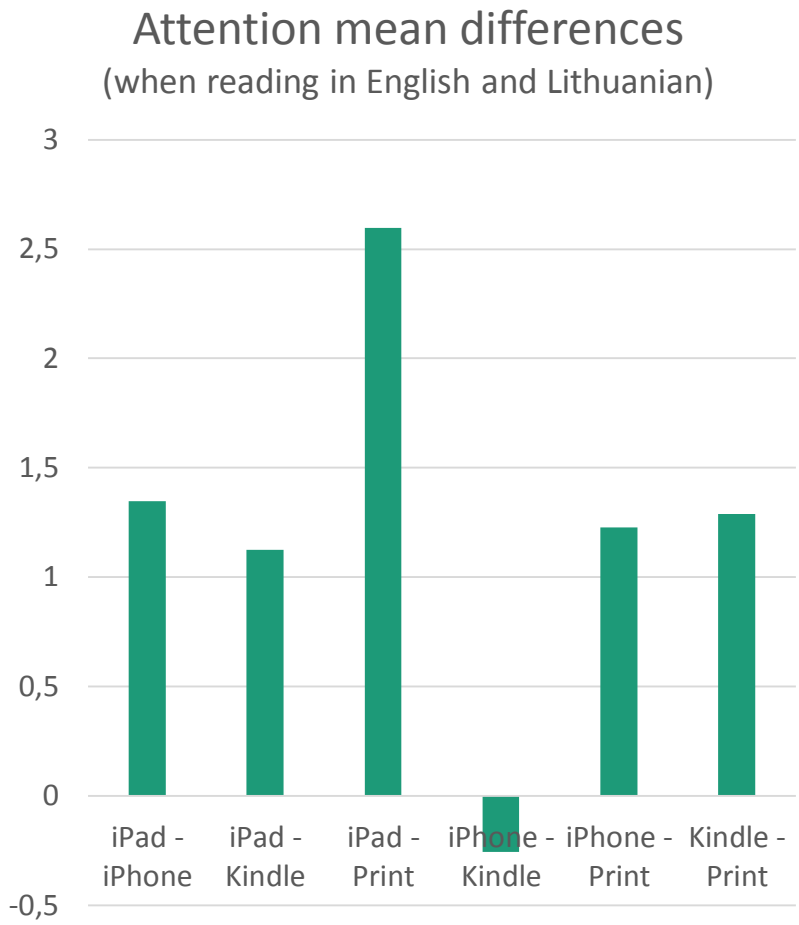
Attention measuring statistics				
	iPad	**iPhone**	**Kindle**	**Print**
Mean	**54.17**	**52.93**	**53.35**	**51.59**
Std. Error of Mean	.432	.381	.441	.428
Median	54.00	53.00	53.00	51.00
Mode	54	53	50	50
Std. Deviation	19.196	16.766	19.613	18.944



Attention mean *differences* and significance between devices

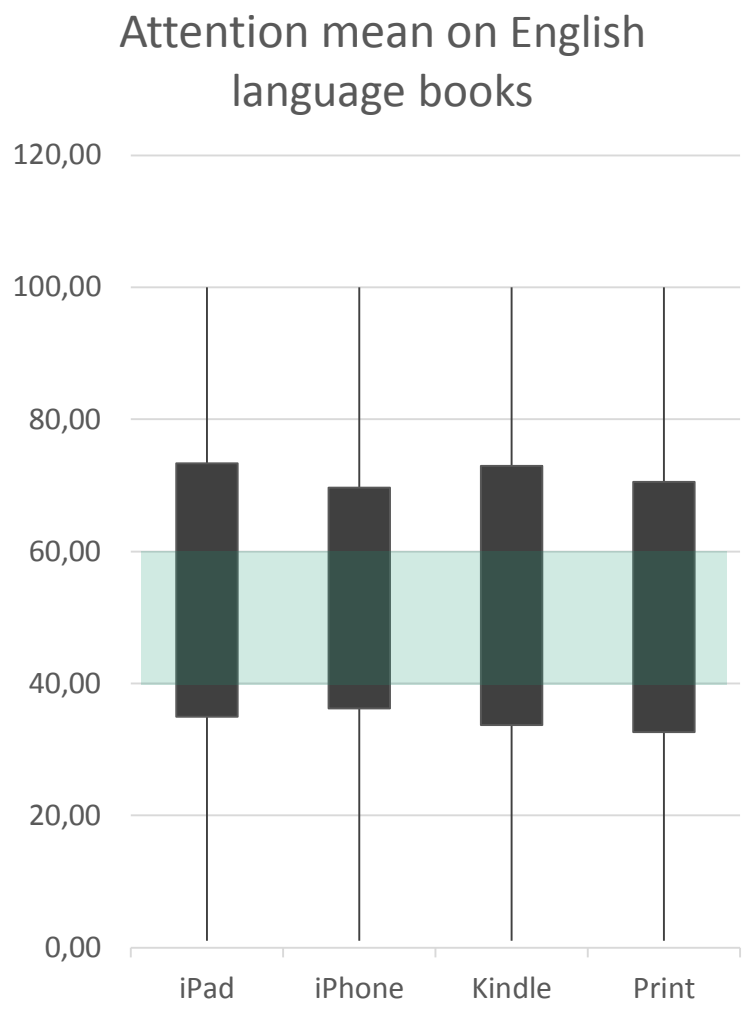
Paired Samples Test							
		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Sig. (2-tailed)
					Lower	Upper	
Pair 1	iPad - iPhone	**1.347**	25.032	.575	.219	2.475	.019
Pair 2	iPad - Kindle	**1.126**	24.430	.557	.034	2.219	.043
Pair 3	iPad - Print	**2.596**	24.754	.566	1.485	3.707	.000
Pair 4	iPhone - Kindle	**-.256**	24.451	.562	-1.358	.846	.649
Pair 5	iPhone - Print	**1.228**	24.107	.556	.137	2.318	.027
Pair 6	Kindle - Print	**1.288**	25.047	.574	.161	2.414	.025

Confidence interval percentage 95%



Attention mean with Std. Deviation

Scale 1-100



eSense scale:

80-100 are considered “elevated”,
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Attention measuring statistics				
	iPad	**iPhone**	**Kindle**	**Print**
Mean	**54.17**	**52.93**	**53.35**	**51.59**
Std. Deviation	19.196	16.766	19.613	18.944

Attention mean between two books (scale 1-100)

BOOK_ID	Average mean
1 book (Christie)	52.78
2 book (Stevenson)	53.24

Preliminary findings

Second stage

1 respondent reading 2 books in English and 2 books in Lithuanian (mother tongue language) for 10 minutes with each device (iPad, iPhone, Kindle, Printed). Total reading time: 160 min.

Attention mean (English vs Lithuanian)

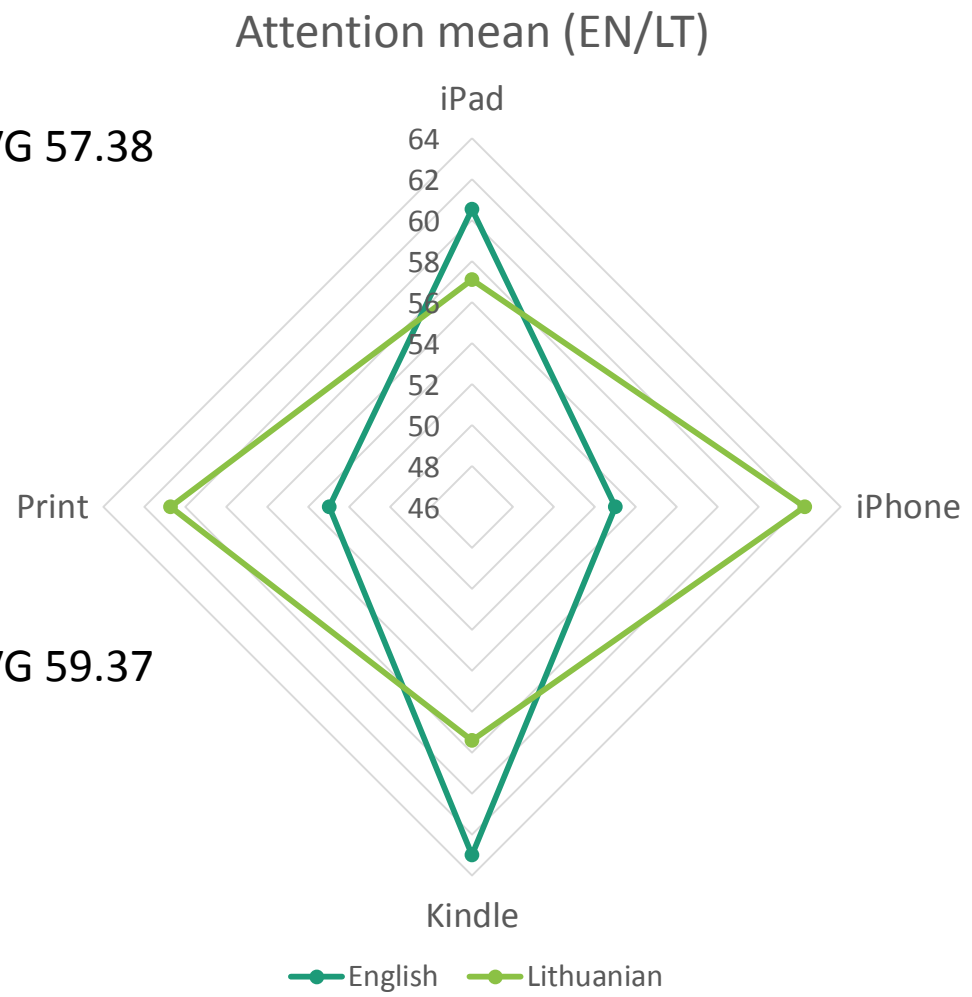
Statistics on English language books				
	EN_iPad	EN_iPhone	EN_Kindle	EN_Print
Mean	**60.52**	**53.01**	**63.00**	**52.97**
Std. Error of Mean	.751	.708	.710	.784
Median	61.00	53.00	63.00	54.00
Mode	56[a]	53	63[a]	44
Std. Deviation	16.517	16.329	16.417	17.668

AVG 57.38

Statistics on Lithuanian language books				
	LT_iPad	LT_iPhone	LT_Kindle	LT_Print
Mean	**57.08**	**62.26**	**57.42**	**60.72**
Std. Error of Mean	.707	.641	.723	.578
Median	56.50	63.00	56.00	61.00
Mode	53	56[a]	54	63
Std. Deviation	16.542	15.122	16.903	13.540

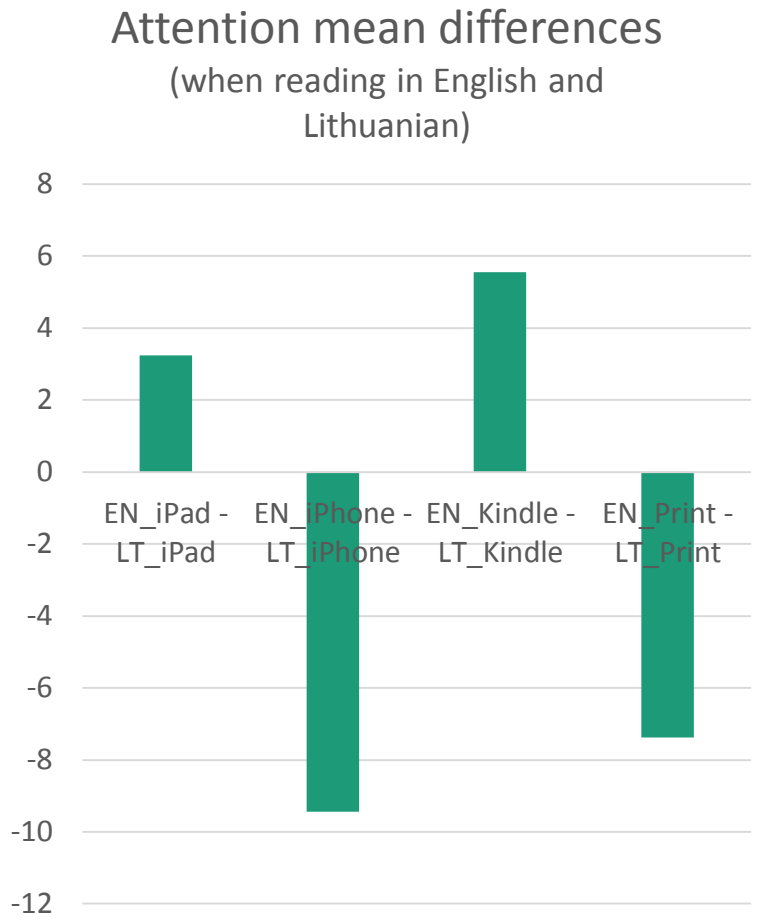
a. Multiple modes exist. The smallest value is shown

AVG 59.37



Attention mean differences and significance between EN and LT language when reading on same devices

Attention (Paired Samples Test)							
		Paired Differences					
					95% Confidence Interval of the Difference		
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	**Sig. (2-tailed)**
Pair 1	**EN_iPad - LT_iPad**	**3.233**	20.881	.952	1.362	5.104	**.001**
Pair 2	**EN_iPhone - LT_iPhone**	**-9.447**	22.045	.958	-11.328	-7.566	**.000**
Pair 3	**EN_Kindle - LT_Kindle**	**5.548**	23.506	1.027	3.530	7.565	**.000**
Pair 4	**EN_Print - LT_Print**	**-7.375**	23.599	1.053	-9.444	-5.305	**.000**



Confidence interval percentage 95%

Preliminary conclusions

- The experiment results (6 respondents, 480 min of reading) when reading in English (foreign) language showed that the *lowest attention level* was measured on printed books and the highest for iPad, but Kindle and iPhone were also close.
- Reading books in English (foreign) language mostly can be considered in *neutral* attention level scale (slihgtly shifted towards 53 with the 1-100 scale). Althought minor part of measurements gets into lower part of *slightly elevated* attention level and some of the values belongs to very upper part of *reduced* attention level.

Preliminary conclusions

- Lithuanian language (native) eSense attention level interval is slightly broader (35-80) to compare with English (foreign language) – 41-77.
- The experiment with one participant on two books reading (160 min) on different languages showed bigger attention level values when reading English book on iPad and Kindle and the opposite when reading Lithuanian book – bigger attention level values on iPhone and printed book.
- No reliable conclusions could be done on device and language differences in attention level. The only can be assumed that is personaly depended and can by a subject for further researching.

Preliminary conclusions

- Preliminary results supposes that attention level measured with MindSet technology can be dependent on person, language (native vs foreign) and reading device.
- Two books used in experiment were close in their genre and there was no significant differencies between attention levels.
- For more accurate conclusions bigger respondents sample and more books with different genres and languages on test needed.

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