Cognitive Load Based Adaptive Assistive Technology Design in Reconfigured Mobile Android Phone

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INTRODUCTION

We designed an adaptive interaction system using R-MAP[1], which is responsive to users' instantaneous cognitive load, can change its response, presentation and interaction flow to improve users' experience and their task performance.

We propose a novel secondary task based virtual sound feedback for cognitive load analysis approach, in line with participant's performance. We analyzed their performance during easy, moderate and complex task experimentation. Although not all participants showed patience to complete all three tasks; we applied z-score normalization on collected data before testing our hypothesis.

The resulting pattern shows significant differences between cognitive performances of blindfolded versus visual impaired and expert (those who have prior smart phone use experience) versus non-experts participating in the experiment.

We also applied machine learning algorithms to classify instances we manually annotated as high load (HL) and low load (LL) considering subjective (questioners) data as a ground truth.

Finally we recommend random forest as a better approach of cognitive load adaptation in R-MAP interface interaction design improvement.

WORKING MEMORY MODEL

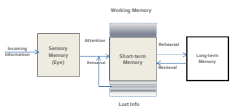


Fig. Human Memory model

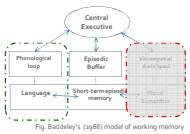


Fig. Baddeley's (1968) model of working memory

Table 1: Cognitive Load Measures

Objective Measures	Task and Performance Measurement	Example: Task completion time, efficiency etc.
	Secondary Tasks	Example: Defining game with difficulty levels, dual-task
	Psycho-physiological	Example: different dependent behavioral data (e.g. heart rate, eye movement, pupil dilation, and brain fMRI, EEG or ECG etc.)
Subjective Measures	Rating Scale	Example: Scoring between the range very low mental effort to very high mental effort

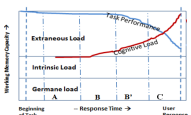
Table 1: Task level vs. cognitive load - *IL-Intrinsic load, EX-extraneous load and GL -germane load

Task level	Task description	Comment
Low Load Task	-No decision task -No memory retrieval task -Good presentation	IL→NO GL→NO EX→NO
Average Load Task	-given a decision task - No memory retrieval task - Good presentation	IL→YES GL→NO EX→NO
High Load Task	-No decision task -Memory retrieval task -Bad presentation	IL→NO GL→YES EX→YES

Visual 'map' for the people who are blind

Andrews, 1983; Fletcher, 1980

The 'deficiency' theory - The lack of visual experience may result in a total lack of spatial understanding;
The 'inefficiency' theory - The lack of visual experience may result in spatial abilities which are similar to, but necessarily less efficient than, those of sighted people; or
The 'difference' theory - The lack of visual experience may result in abilities which are qualitatively different from, but functionally equivalent to, those of sighted people.



A-Normal load, B, B'-Average Cognitive load, C-Cognitive overload section.

Fig. Working memory capacity and cognitive load

SMART PHONE AS AN ASSISTIVE TECHNOLOGY TOOL

R-MAP: Reconfigured Mobile Android Phone

-Developed in CVPIA Lab, The University of Memphis, 2010.

What is R-MAP?

- ✓ a fully integrated, stand-alone system with easy-to-use interface to reconfigure an Android mobile phone.
- ✓ designed and developed to facilitate day-to-day activities of people who are blind or visually impaired.

Key services

- ✓ Reading out loud "printed text" on various types of surfaces such as "printed letter", "medicine bottle", "street sign" and etc.
- ✓ Providing a sense of direction in an open space,
- ✓ Enhancing shopping experience through integrated barcode reading service, and
- ✓ Assistance for indoor navigation.

R-MAP operation - four steps

Step-1: Open application,
Step-2: Enter into capture mode.
Step-3: Capture image, Pause for 5-20 sec.
Step-4: Speech (Voice o/p).

THE EXPERIMENT

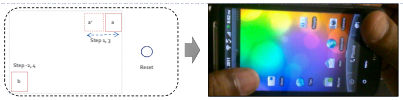


Figure 3. R-MAP mini-shallow structure interface Layout

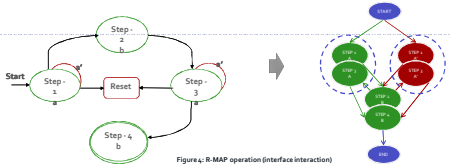


Figure 4: R-MAP operation (interface interaction)

Step-1: a- Open application, // a' - *Virtual sound alert (VS1 or VS2)*,
Step-2: b- Enter into capture mode.
Step-3: a-Capture image, // a' - *Virtual sound alert (Vs1 or VS2)*,
Pause for 5-20 sec.
Step-4: b- Speech (Voice o/p).

Virtual Sounds (VS1): A spatial shift of first push location in figure (*'a' to 'b' or 'b' to 'a'*) in R-MAP is made with a sound feedback.
Virtual Sounds (VS2): Instructs subject to push the reset button

Subjective rating
Intrinsic load "*How difficult was the learning instruction content for you?*". Extraneous load "*How difficult was it for you to learn with the instruction format?*" and Germane load "*How much did you concentrate during learning process?*".
Secondary Task Rating
Scored based on subjective performance on secondary task. Three tasked (Easy, Moderate, and Complex) are assigned, scored are normalized before t-test.

RESULTS

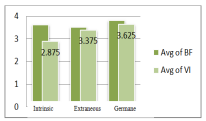
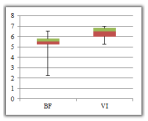
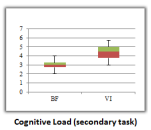


Fig. Intrinsic, extraneous and germane for Blindfolded and Visual impaired Subjects

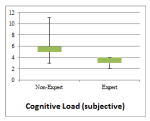


Cognitive Load (subjective)



Cognitive Load (secondary task)

Fig. Cognitive Load Blindfolded vs. Blind people



Cognitive Load (subjective)

Cognitive Load (secondary task)

Fig. Cognitive Load Expert vs. Non-expert people

Tables 1. Sample data
*n- novice user, y- expert user, M- Male, F- Female, BF- Blind-folded, BP- Blind People,
E- Easy, M-Moderate, C-Complex, CLI – cognitive load index, HL – high load (Overload), AL – Average load*

User-ID	Age	Ethnicity	Subject No	Gender	Smart Phone	# of Tasks	Task types	Task-1	Task-2	Task-3	Error	CLI	Load Type
User-1	29	Asian	BF	M	N	1	E	3	-1	-1	3	3	HL
User-4	31	American	BF	F	Y	3	E,M,C	0	1	3	4	1.333333	AL
User-7	30	African	BF	F	Y	2	E,M	0	4	-1	4	2	HL
User-10	30	American	BF	M	N	2	E,M	0	3	-1	3	1.5	AL
User-25	42	American	BP	M	Y	3	E,M,C	0	1	2	3	1	AL

	Cognitive Load (Subjective)		Cognitive Load (Secondary Task)	
	M	SD	M	SD
Blind Folded (N =20)	5.2	0.95	3.65	0.93
VP (N =4)	6.312	0.77	4.25	0.96
t-value	2.5193		1.1489	
p-value	0.0532		0.3146	

	Cognitive Load (Subjective)		Cognitive Load (Secondary Task)	
	M	SD	M	SD
Non-Expert (N=12)	6	2	3.73	0.79
Expert (N=12)	3.33	0.65	2.73	0.90
t-value	4.391		0.361	
p-value	0.0007		0.0123	

CONCLUSION

We experimented so far...

- ✓Differences in cognitive load between expert participants (who have prior smart phone use experience) vs. non-expert (no prior experience) while using assistive technology (R-MAP);
- ✓Differences in cognitive load and usability between blind folded participants and participants who are blind or visual impaired;
- ✓The impact of visual mapping capability of blind folded people over visual impaired. Also
- ✓The impact of a mini-shallow structure interface with secondary task based cognitive load measures to the assistive technology people.
- ✓The difference of training by blindfolded and blind subjects in operation of assistive tool like R-MAP.
- ✓OCR performance and Usability studies of R-MAP

Classifier	Accuracy (%)	Kappa
J48	72	3.91
Random Forest	78	4.32
Naïve Bayes	67	3.56

Table 3: Performance Classification

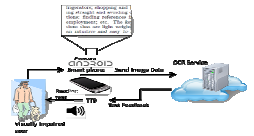
Future Work

- ✓Finding sense of direction in an open space
- ✓Navigating unfamiliar indoor locations using sparse digital maps
- ✓Access to affective states of the surrounding individuals
- ✓Providing guidance during extreme conditions, such as flood, hurricane, or earthquakes.

ON GOING PROJECTS

Smart phone meets the Cloud for Blind Ambition

- Utilizing the service oriented computing architecture;, cloud computing
- ¨ Enhancing their experience in sensing the environment they live in.
- ¨ Improving the quality of their lives.



What about the sighted users?

The applications will be useful even for sighted users when they don't want visual engagement with smart phones.

Recent Works

1. Akbar S. Shaik, G. Hossain, and M. Yeasin. 2010. **Design, development and performance evaluation of reconfigured mobile Android phone for people who are blind or visually impaired.** In Proceedings of the 28th ACM International Conference on Design of Communication (SIGDOC '10). ACM, New York, NY, USA, 159-166.
2. G. Hossain, Akbar S. Shaik, and M. Yeasin. 2011. **Cognitive Load and Usability Analysis of R-MAP for people who are blind or visually impaired.** In Proceedings of the 29th ACM International Conference on Design of Communication (SIGDOC '11). ACM, New York, NY, USA.
3. G. Hossain, ASM Iftekhar Anam, Mohammed Yeasin and Akbar S. Shaik. 2011. **Cognitive Assistive Technology for Teaching and Learning with Smart Phone.** Poster presented IEEE conference of Mobile Technology for Teaching & Learning conference, Oct 18, The University of Memphis, TN, USA.

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