Effects of Physical Capabilities on Interaction

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Abstract
In this work, we investigated how physical capabilities of users with a wide range of abilities are reflected in their interactions with digital devices. In particular, we investigated the principles of visual perception of visually impaired people and rapid aiming movements of motor-impaired users and also compared those with their able-bodied counterparts. Our studies and results should help interface designers to design inclusive systems and will also enrich cognitive science by explaining the effect of physical capabilities on interaction.

Categories and Subject Descriptors
H.5.2[Information interfaces and presentation]: User interfaces – theory and methods; **K.4.2 [Computers and Society]**: Social Issues – assistive technologies for persons with disabilities.

General Terms
Experimentation, Human Factors, Measurement, Theory

Keywords
Human Computer Interaction, Visual Perception, Hand-strength Evaluation, Rapid Aiming Movement.

INTRODUCTION
One of the basic aims of any interface designer is understanding users. There are many different ways and aspects of understanding users- in this work we investigated how physical capabilities of users are reflected in their interaction with digital devices. Physical capabilities spans through a wide range among users based on age, gender and presence of physical impairments. Lack of knowledge about the problems of disabled and elderly users has often led designers to develop non-inclusive systems. There are guidelines for designing accessible systems (particularly accessible websites), but designers often do not conform to the guidelines while developing new systems. We investigated the principles of visual perception of visually impaired users and motor-action of motor-impaired users and also compared those with their able-bodied counterparts. Our studies will provide the necessary knowledge about the relationship between physical ability and interaction, which will help designers of interactive systems to develop more inclusive systems. We have already used our study to design user models of people with a wide range of abilities [1]. Our models can be used to determine the optimum font size, contrast and colour of on-screen menu items used to select channels in a digital TV. Similarly, it can also be used to simulate the perception of visually impaired users [2] (like how a person having less visual acuity will view a remote controller) to make designers understand the problems of visual impairment.

ANALYZING PERCEPTION
We designed an experiment to record and analyze eye gaze of visually-impaired and able-bodied users during a visual search task. The task involves searching a shape or icon from a set of distractors. The eye gazes of users were tracked by using a Tobii X120 eye-tracker [4]. Figure 1 shows the average search time for able-bodied users and the same for each visually-impaired user. As expected, the visual search time is greater for visually-impaired users (P1 to P8) than for able-bodied users.

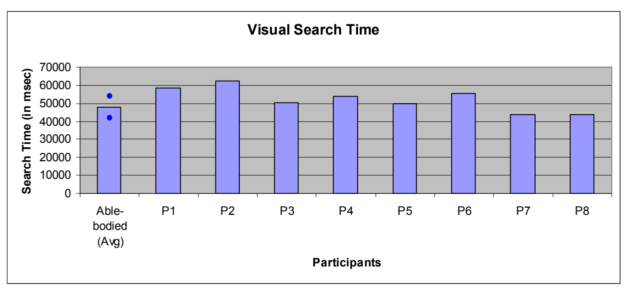

Figure 1. Visual Search Time

If we consider the 'spotlight' metaphor of visual perception, a visual search task consists of mainly two steps

- Focusing attention at the probable target
- Moving eye gaze to the next probable target

So we analyzed the details of eye-gaze fixation and eye movement trajectories. We found in the eye tracking data that users often fixed attention more than once on targets or distractors. We investigated the number of fixations with respect to the fixation durations. Figure 2 shows the total number of fixations with respect to the maximum fixation duration. It can be seen that as the fixation duration increases, the number of fixations also decreases. This can be explained by the fact that when the fixation duration is higher, the users can recognize the target and do not need more fixations on it. The number of fixations is smaller when the fixation duration is less than 100 msec, probably these are fixations where the distractors are very different from the targets and users quickly realize that they are not intended target. We also investigated different strategies to explain and predict the actual eye movement trajectory. We did not find any difference in the eye movement patterns of able-bodied and visually impaired users.

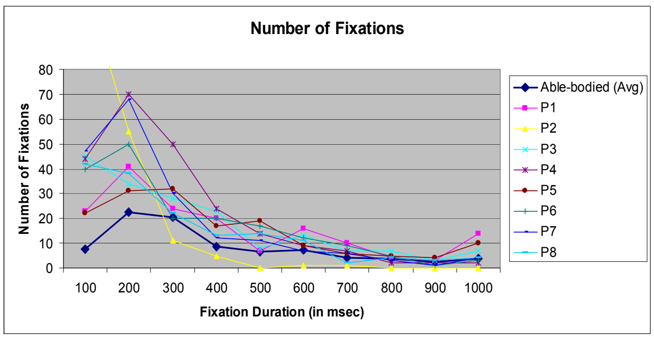

Figure 2. Number of Fixations w.r.t. Fixation Duration

This is due to the fact that the V4 region in brain controls the visual scanning and our visually-impaired participants did not have any brain injury and so the V4 region worked same as the able-bodied users. However visually-impaired users had more number of attention fixations which made the search time longer. The difference between the numbers of fixations for able-bodied and visually impaired users is more prominent for shorter duration (less than 400 msec) fixations. Perhaps this means visually impaired users need many short duration fixations to confirm the recognition of target. From an interface designers' point of view, these results indicates that the clarity and distinctiveness of targets are more important than the arrangement of the targets in a screen. Since the eye-movement patterns are almost same for all users, the arrangement of the targets need not to be different to cater visually-impaired users. However clarity and distinctiveness of targets will reduce the visual search time by reducing recognition time and number of fixations as well.

ANALYZING MOTOR-BEHAVIOUR

In any graphical user interface, a significant portion of interaction consists of pointing tasks. We analyzed and compared pointing performances of motor-impaired and able-bodied users. We made a novel approach of relating hand strength of users with their pointing performance. We found that, for motor-impaired users, the mean and standard deviation of the velocity of pointer movement significantly correlates with the grip strength (Figure 3, $\rho = 0.82$, $p<0.001$ for mean and $\rho = 0.81$, $p<0.001$ for standard deviation). We also found that for able-bodied users grip strength and tip pinch strength significantly correlate with the Index of Performance of a 2-dimensional Fitts' Law [3] task ($\rho = 0.57$, $p < 0.05$ for grip strength, $\rho = 0.72$, $p < 0.005$ for tip pinch strength). Our analysis indicates that people having higher hand strength also have greater control in hand movement and can perform pointing faster. Our analysis also showed that flexibility of motion (as measured by the Range of Motions of wrist or fore-arm) is not as important as strength of hand (as measured by grip strength). We also found similar result for able-bodied users. The positive correlation between index of performance and hand strength shows people with greater hand strength perform pointing faster.

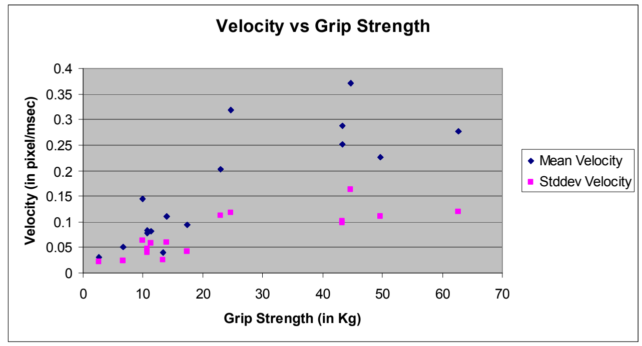

Figure 3. Grip Strength vs. Velocity of Movement

CONCLUSIONS

In this work, we investigated how physical capabilities of users with a wide range of abilities are reflected in their interactions with digital devices. We found that the eye movement patterns are almost same for visually impaired and able-bodied users. However, visually-impaired users fix eye-gaze more number of times than their able-bodied counterparts, which made the visual search time longer. Our study on motor-impaired users indicates that people having higher hand strength also have greater control in hand movement and can perform pointing faster. These studies and results should help interface designers to design inclusive systems and will also enrich cognitive science by explaining the effect of physical capabilities on interaction.

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