Comfort and Discomfort in a Chair Using the Smartphone

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Abstract This paper presents the results of an experiment studying the effect of arm support on smart phone use. A chair with a special arm support for smart phone use was developed and tested by 24 participants. The participants were asked by a questionnaire for their comfort and discomfort perception after using the chair with and without armrest for 15 minutes. The effects on posture and productivity were tested. Productivity was tested by counting the number of typed characters and spelling mistakes. There was a non-significant trend that the word count of users in the smart phone chair without arm rest was higher than with arm rest and the spelling mistakes of users in the chair without armrests were lower than in the seat with arm rests ($p < 0.05$). Comfort and Discomfort were evaluated using a questionnaire. The discomfort and comfort differed for the total body, neck, upper back, lower back, lower arm, wrist and leg , but not significantly. Only the upper arm in the condition with arm support showed a higher discomfort and a lower comfort ($p < 0.05$). The posture of the participants was analysed using Kinovea software for the body angles and were processed further using a RULA assessment. The results show that the potential ergonomic risk when people used the smart phone in the chair without arm support is lower than when they used the chair with arm rest ($p < 0.05$). In conclusion, the arm rest increased discomfort of the upper arm of participants, probably because it limits the freedom of movement or because the arm rest is not height adjustable.

Keywords: smartphone, productivity, body posture, chair, texting, comfort

1 Introduction

A survey among 1,500 office workers in the UK and Australia found that nearly half of today's employees use a smartphone or mobile in the work place (abc.net.au, Dec 2012). Much effort is devoted to optimizing the systems and mechanisms of smart phones to increase productivity (e.g. Jewell, 2011; Lee and Lee, 2011). Some milliseconds of improvement seem very important. However, the relationship between smart phone productivity and body posture is seldom mentioned, while the effects could be larger than milliseconds. The users of smart phones are often not aware of their body posture and the question is whether they have tacit knowledge on the body postures that improve smart phone productivity, which is the theme of this study. Body posture research concentrates mostly on the relationship with musculoskeletal complaints or emotions. For instance, a literature review by Gallegher (2005) comes to the conclusion that workers who adopt unusual or restricted postures are at higher risk of musculoskeletal complaints and often exhibit reduced strength and lifting capacity. Regarding emotions Riskind and Gotay (1982) found for instance that the more slumped-over body posture may have led to infer greater helplessness. However, research on the relationship between body posture and productivity is scarce. A search in “science direct” on the terms ‘body posture’ AND ‘productivity’ in title, keywords or abstract showed 8 papers between 1996 and December 2013. Four of these consider human productivity. One of these four papers showed a significant difference in productivity between two assembly work station lay-outs (Lim and Hoffmann 1997). The layout influenced body posture and productivity was increased through more economical use of hand movements. In computer work the number of studies on body posture and productivity is also limited. Some studies, which do not primarily focus on productivity, also measured performance effects. For instance, Moffet et al. (2002) showed that the number of typed characters was significantly higher using a screen positioned closer to the eyes. Sommerich et al. (2002) found differences in productivity between using a notebook computer stand-alone and along with inexpensive peripheral input devices. Participants were more productive with the mouse than with the pointing stick. However, effects on productivity of other postural changes were not found. The changes in parts of the human body in space were small, but significantly different. In a pilot study Commissaris et al. (2008) showed that various office work postures influenced productivity. For instance, an asymmetric posture with the back bent sideward reduced productivity for a VDU task.

So, there are indications that large body posture changes can influence productivity, and it is interesting to know if this is true for the now much used smart phone. Perhaps the smart phone or chair should be designed in such a way that a more productive posture can be taken. Therefore, the first research question for this study is *“Does body posture while using a smartphone influence productivity, comfort and discomfort?”*

To test the assumed effect of large body posture changes on productivity an experiment was performed. In this research productivity is defined as typing performance. First pilot tests were performed to improve the test set-up and the questionnaires. For instance, letters in the pilot texts shown on a paper were too small to read and type size in the smart phone was made larger in the real test as we did not want to measure readability. Pilot tests were also done in developing an armrest chair (se fig. 1) to design the ideal smartphone chair to support the arms in an adequate way.

Fig.1. *Various stages in the development of the armrest chair, supporting working with a handheld device. Left: one of the first drawings, middle: the first test version, right: the final prototype used in this experiment.*

2 Methods

The two research questions “Does body posture while using a smartphone influence productivity?” and “Does body posture while using a smartphone influence comfort and discomfort?” were answered by means of an experiment. The research team were provided materials and method to answer the question.

2.1 Participants

Thirteen men and 11 women of various nationalities (European, American and Asian) participated in the study. Their average age was 25.2 years (20 to 40 years) and the average length was 1.74 m, varying from 1.58 to 1.89 m.

2.2 Measurements and protocol

A pilot test was set up to simulation the planned experiments. One participant participated and followed the planned protocol, that was set up by the research team (see table 1)

Table 1 : the protocol of the smartphone seat experiment.

Introduction and Observation for 10 minutes	Start typing text scenario 1 for 15 minutes, send an email	Rest (change posture) for 5 minutes	Start typing text scenario2 for 15 minutes, send an email	Answer comfort and discomfort questionnaire

After the pilot test, the participant provided comments, on the basis of which the questionnaire was improved. A body map picture was added to stimulate a more effective communication and an explanation of the difference between comfort and discomfort was added. These improvements were implemented for the next participants.

When each participant arrived, the first ten minutes were spent explaining the research protocol and the participant completed an informed consent. The participants were invited to observe the previous participant while this previous person was sitting in the chair and typing.

The 24 participants were asked to type as fast as possible a text on their own smartphone during fifteen minutes in each chair. The chair was presented in two different conditions: with and without armrest. The texts were different in each condition, but had the same type of words. To prevent order effects the sequence of seat use was systematically changed. The participants had to read the texts they were asked to type from a screen in front of them at the appropriate eye height. Video recordings were made to see if the participants used the same typing method in all chair conditions (e.g. using both thumbs in typing, using right finger etc.). The participant typed this text on their own smart phone (the smart phone they are used to) and had to send the typed text to an email of the researcher. 12 participants started in the chair with armrests and other started typing in the chair without armrests. Finally, the participants were asked to rate the perceived comfort and discomfort for each condition on a 7-point Likert scale (1 represents the lowest comfort and discomfort, 7 represents the highest comfort and discomfort) after typing. See Fig 2 sitting in a chair with and without armrest.

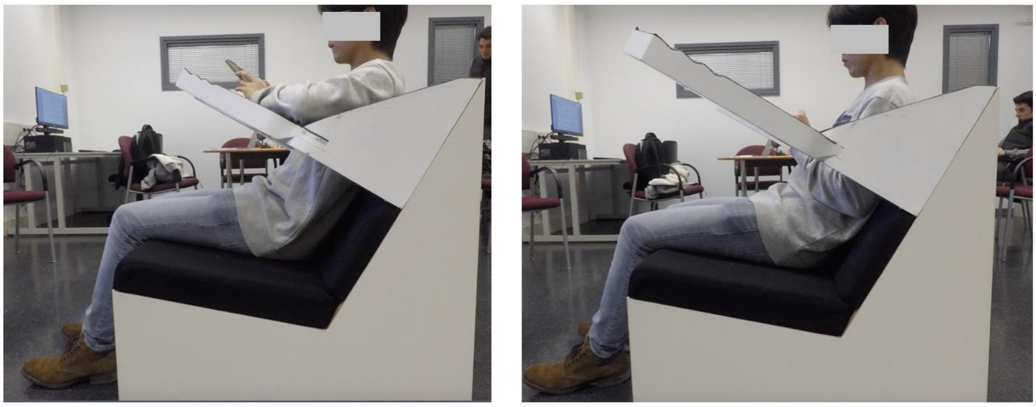

Fig.2. *A chair with and without armrest.*

2.3 Questionnaire

In order to evaluate comfort and discomfort, participants were asked to indicate with a cross on a map of the human body in which region they experienced comfort and discomfort. The sum of the total body, neck, upper back, lower back, upper arm, lower arm, wrist and leg comfort and discomfort was calculated as well as the total of comfort and discomfort regions and compared between the two chair conditions. All participants were encouraged to write a text under the topic "additional comments". If more than 10% of the participants had similar comments in the open questions these were reported.

2.4 Posture recording

The posture of participants, when they used a smartphone while typing in the chair with and without armrest, was analysed by scoring the angles by using the Kinovea software and then evaluated on ergonomic risk by RULA. The participants used the same posture of the upper limb in the left and right side.

2.5 Analysis

A Wilcoxon test for within participant comparison was used to compare the 2 chair conditions ($p<0.05$). Comfort, discomfort, and productivity were compared with Wilcoxon test as these are usually not normally distributed. The postures were observed and recorded between the two chair conditions and the angle of upper to lower body analysed using the Kinovea program and Rapid Upper Limb Assessment (RULA) to estimate the ergonomic risk when using the smartphone in the two different seat conditions.

3 Results

The results of this study are reported in three parts: productivity, posture and comfort and discomfort with 24 participants.

3.1 Smartphone productivity in two different chairs with and without armrest.

The productivity averaged for each condition over the 24 participants (age varying from 20 to 40 years; length varying from 1580 to 1890 mm; all of higher education), expressed as words counted, was lower when participants used the smartphone chair in the condition supported by the armrest than without armrest. However, the diference was not significant, p-value 0.18406 . There were significantly more mistakes, spaces, and wrong letters when participants used the smartphone chair with armrest than without armrest, (p-value 0.00001).

Table 2. Word count, mistakes, spaces and wrong letters

Type of chair	*Word count*			*Mistakes, Spaces and wrong letters*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
Chair with arm rest	172	313	416	6	20	52
Chair without arm rest	156	304	418	5	14	31
Significance level	0.18406 ; not significant.			0.00001 ;significant		

3.2 The results of Postures

The results from RULA showed that when the participants used the smartphone with arm support the risk was higher than when they used the smartphone in the chair without armrest at a significant level, p-value 0.00001.

Table 3. The average RULA score separated by part of body.

Posture	*Upper arm*	*Lower arm*	*Wrist*	*Wrist Twist*	*Neck*	*Trunk*	*Leg*	*RULA Score*
Smartphone chair with armrest	5	2	2	1	2	1	2	5
Smartphone chair without armrest	1	2	2	1	2	1	2	4
Significant Level	0.00001 ; Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	0.00001 ; Significant

The RULA score is separated by 15 items. Column A shows the arm and wrist analysis, column B the neck, trunk, and leg. The results of the RULA score are the same on the left and right side of the body. None of the body parts were significantly different. The only difference at a significant level was in the upper arm: the score was higher in the chair condition with armrest than in the chair condition without armrest.

3.3 The results of comfort and discomfort

The participants evaluated their comfort and discomfort after sitting in the chair with and without armrest and typing the text for fifteen minutes in each chair. On the one hand, the total body, neck, upper back, lower back, lower arm, wrist, and leg comfort and discomfort between the with and without armrest were not significantly different (P-value 0.05). On the other hand, upper arm comfort when using the chair with armrest was lower than without armrest. Moreover, participants' discomfort when using the smartphone on the chair with armrest was greater than when using the smartphone without arm support.

Table 4. The minimum, average and maximum level of comfort and discomfort

Part of body	*Comfort*						*Significant level*	*Discomfort*						*Significant level*
	Min(1)		*Average*		*Max(7)*			*Min(1)*		*Average*		*Max(7)*		
	+ arm rest	*- arm rest*	*+arm rest*	*- arm rest*	*+ arm rest*	*- arm rest*		*+ arm rest*	*- arm rest*	*+ arm rest*	*- arm rest*	*+ arm rest*	*- arm rest*	
Total body	1	2	3.75	4.00	7	7	0.43251	1	1	3.67	3.75	7	6	0.48006
Neck	1	1	3.75	3.46	6	7	0.40517	1	1	3.67	4.54	7	7	0.7493
Upper back	1	2	4.42	4.29	7	6	0.49202	1	1	3.25	3.63	6	6	0.28774
Lower back	2	2	4.63	4.29	7	7	0.30153	1	1	2.92	3.17	7	6	0.2451
Upper arm	1	2	3.33	4.21	6	7	0.02275*	1	1	3.79	3.71	7	6	0.04947*
Lower arm	1	2	3.83	3.75	6	7	0.44828	1	1	3.71	4.04	7	6	0.35569
Wrist	1	2	3.83	4.17	6	7	0.15625	1	1	3.25	3.54	7	6	0.38974
Leg	3	3	4.96	4.96	6	5	0.5	1	1	2.63	2.58	5	6	-**

* The part of body that show significant difference.
** The data in this part were the same level, not compared by the Wilcoxon test.

The comfort differed significantly between the two chair conditions for some parts of the body such as upper arm. For other body parts the results did not significantly differ between 2 chairs, but the participants reported low comfort and high discomfort. For example, in the chair condition with armrest, comfort at the neck, lower arm, and wrist was higher than other part of body, with the average level at 3.75, 3.83 and 3.83 respectively. Moreover, the level of discomfort in the chair condition with an armrest at the neck, lower arm, and wrist was 3.67, 3.71 and 3.25 respectively. The results when using the smartphone in the chair without armrest showed the comfort level of the neck and lower arm were lower than that of other parts of the body. The results showed values of 3.46 and 3.75 respectively. The level of discomfort was higher than for other part of body, with a level of 4.54 and 4.04. That indicated the smartphone chair needs to be redesigned to improve comfort and reduce discomfort at the neck, upper arm, lower arm and wrist.

4 Discussions

Answering the research question, “Does body posture while using a smartphone influence productivity?”, the results illustrated that productivity of word count is different between the participants using the smartphone in the chair condition with and without armrest, but not at a significant level for all recordings. The errors such as mistakes, spaces and wrong letters were significantly fewer when the participants used the smartphone without armrest than with armrest. This is aligned with the study of Liao and Drury (2000) who found that postural discomfort might have an effect on typing performance. The error rate did not increase progressively with the work duration. The error rate increase with Borg scale ratings, but there was a not significant work interval effect. However, they mention that the test time was for 2 hours. Pan et al. (1994) reported that 2 hours may not appear to be a long work duration. In addition, they tested with 6 participants and a large sample size was recommended in the further study.

In a pilot study Commissaris et a (2008) showed that various office work postures influenced productivity. For instance, an asymmetric posture with the back bent sideward reduced productivity for a VDU task.

Regarding the second research question, “Does body posture while using a smartphone influence comfort and discomfort?” The study showed that there is no significant difference between most of the body parts regarding the comfort level. The total body, neck, upper back, lower back, lower arms, wrist, and legs were not significantly different between the chair conditions with and without armrest while using a smartphone. Only for the upper arms, there was a clear significant lower comfort score in the condition with armrest. Also, the discomfort while using the smartphone on a chair with armrest was significantly higher than without armrest. According to the results of RULA, there is no difference between the left and right side of the upper body. The posture during smartphone use in the chair without armrest has a significantly lower risk than with armrest according to the RULA evaluation method. Notably, the upper arms showed a significant difference, because of the height at which the armrest was installed without adjustability at 55cm height from seat level. While the results of comfort and discomfort between two chair conditions provided a significant difference only in the upper arm, other body part were not significantly different. Still, the results showed low comfort and high discomfort scores, for example, in the neck, lower arm, and wrist. Also, Van Veen et al. (2014) reported about neck, arms, and hand comfort and discomfort in a comparison between using the table in a chair with and without armrest. The results of their Wilcoxon Signed Ranks test showed that comfort of the neck region increases significantly while sitting in a chair with armrest, but arms and hands were not significantly different. Moreover, discomfort decreases significantly for the neck, but arms and hands were not significantly different. They were able to adjust the height level of arm support to fit the participant’s anthropometry. This might have been a crucial element. Albin and Mcloone. (2014) reported that the tilt angle of a tablet increases, the neck flexion decreases significantly. Therefore, perhaps in a future design the arms should be made height adjustable to prevent that the shoulders will be lifted and still improve the position of the neck. Another option is that the arm rest limits the freedom of movement and forces the participants in an unnatural posture. Moreover, the comfort score of the arm are in alignment with the RULA scores showing that the chair needs to be improved.

5 Conclusions

In this study, no significant difference in the productivity of word count was found between a chair supporting the arms in using a smart phone and a chair without armrest. However, errors such as mistakes, spaces and wrong letters occurred significantly more frequently when using a smartphone with arm support than without arm support.

This study also found a significant difference in posture from the ergonomics risk assessment level using RULA. The ergonomic risk level was lower without than with the armrest. No significant difference was found in total body, neck, upper back, lower back, lower arm, wrist and leg comfort and discomfort. In the condition without arm support, only upper arm comfort increased while discomfort decreased, both significantly. Further research should focus on the design of the armrest and on productivity, posture, comfort, and discomfort when using the smartphone for a long time. It is advised to study height adjustable armrests.

Acknowledgments The research work reported here was made possible by The Royal Thai Scholarship.

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