Mobile work with tablet and smartphone: on the method dependency of an assessment of physical stress and strain

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Abstract. Smartphones and tablets support mobile work to a great extent. According to German Workplace Ordinance, however, portable display devices should only be used for a short time. This study focuses on time-based differences in discomfort and posture while using smartphones or tablets, of 64 participants aged 18-65 years documented in two half-hour trials on either device. The posture of the participants was continuously recorded by the experimenter using RULA. Before and after each trial, participants rated their current musculoskeletal discomfort. While the RULA scores indicate a low to medium risk of musculoskeletal disorders, subjective discomfort ratings remained low for the entire experiment. The results underline the importance of risk assessments in the work context, since the individual perceptions may not be a reliable measure of the physical stress caused by the use of touchscreen devices.

Keywords: Mobile Device, Touchscreen, Workplace, RULA, Physical Strain, Discomfort

1. Background

Mobile devices allow flexible access to information nearly anytime anywhere (Messenger 2019). Information can be documented on the fly without detours via paper notes and the associated duplication of work. Thereby, they offer potential to facilitate work especially information processing tasks. The more mobile the aspect of work is, the more suitable it is to work with hand-held devices such as tablets and smartphones, e.g. in electronic maintenance documentation or for mobile situational risk assessment.

At the same time, a growing number of studies report participants showing highly repetitive hand or arm movements and/or working in unfavorable postures associated with smartphone and tablet use (Gustafsson et al. 2018; Lin et al. 2017). Depending on the tasks and the device studied, participants bent their neck more than 20° sometimes exceeding 40° compared to a neutral upright posture (Douglas & Gallagher 2017; Ning et al. 2015). A study analyzing the ergonomic risk to smartphone users while texting a short sequence using the Rapid Upper Limb Assessment (RULA) reported rather high levels of ergonomics risk (Namwongsa et al. 2018). The intensity of use is associated with pain in the neck, arm or wrist as well as psychological discomfort (Gustafsson et al. 2018; Sharan et al. 2014).

This begs the question of how to take advantage of the benefits that mobile devices undeniably bring to work without creating additional risks for the employees. According to the German Workplace Ordinance, portable visual display screen equipment should only be used for short periods of time or at workstations where the work tasks cannot be performed with any other (Schedule No. 6.4 § 3 ArbStättV).

As current studies provide little information on preferable use duration with regard to OSH, we aim to provide a first step regarding a healthy length of use in the workplace. The following laboratory study focuses on time-based differences using smartphones or tablets for a documentation task concerning:

- levels of ergonomic risk assessed via RULA,
- reported differences in comfort in various body parts over time,
- subjective changes of mental and physical workload,
- correlations between subjective ratings and the level of ergonomic risk.

2. Method

2.1 Participants

Sixty-four asymptomatic adults (32 females, 32 males) with a mean age of 41 years (SD 15.0) participated in the study. They were recruited through public boards and lab internal mailing lists and received an expense allowance of 10 € per hour.

Procedures were approved by the Federal Institute for Occupational Safety and Health (BAuA) Ethics Committee (017_2018) and all participants provided written, informed consent prior to the experiment. The sample size satisfied the number of samples to achieve a statistical power of .80 based on a critical α-value of .05 and a .50 correlation between repeated measures as conducted for a mixed ANOVA in G*Power (Version 3.1.9.2).

2.2 Tasks and Procedure

At 20-second intervals landscape-format photographs were projected onto a wall at a size of approximately 100 x 150 cm. Placed at three meters distance, each participant recorded the contents using a checklist in two trials for half an hour each. They started with questionnaires regarding their gender, age, digital affinity, and any current musculoskeletal discomfort. After they familiarized themselves with the technology and the task, the first trial started. Participants selected which of 15 specific details they saw in the picture by tapping checkboxes (yes/no) as fast and accurately as possible. They could start at any point on the list. With each image change, they switched to the next checklist. After six photos, participants assessed their subjective workload based on a visual scale and continued with the next six-picture sequence. After 30 minutes participants rated their musculoskeletal discomfort a second time. Following a 10-minute break, they started the second trial. Finally, each participant assessed their current musculoskeletal discomfort for the third time.

32 participants used a 7‘‘-Tablet (Galaxy Tab A T280, 283 g) and the others a 6.3‘‘ Smartphone (Samsung Galaxy Note 8 N950F, 195 g). Devices were held in the portrait orientation. Participants could choose the hand holding the device. They were free to vary the hand as well as their posture during both trials. Participants had no arm supports during the entire test period.

2.3 Dependent variables

Posture: The experimenter recorded the participants’ posture during each trial using the Rapid Upper Limb Assessment RULA (McAtamney & Corlett, 1993). A higher General Score indicates higher deviations from a neutral position and subsequently a higher ergonomic risk (level 1 negligible risk - level 4 very high risk). The experimenter

assessed the hand holding the device, changing the body side whenever participants changed the holding hand. Thus, there are no separate scores for the left or right side. At the beginning of each trial, a participant's posture was recorded in all joints simultaneously. Subsequently, after each postural change, the resulting angle in the joints involved was registered. Apart from the initial posture, no information is available as to which positions co-occurred in various joints. Due to this, first, we used all individual joint angles with the lowest deviation from a neutral body posture loads to determine a minimum Grand Score per participant per trial. Second, all joint angles with the greatest deviations from a neutral posture were selected in order to calculate the maximum Grand Score of a participant per trial.

Discomfort: Participants rated their musculoskeletal discomfort on 11-point Likert scales from 1 (not at all) to 11 (very severe). The questionnaire included separate scales for the neck, upper and lower body, shoulders, forearms, hands, thumbs and fingers. As there were no statistical significant differences between both half of the body, scores for the right and left side were combined for the subsequent analyses.

Subjective workload: Participants rated their subjective physical and mental load via an 11-point one-item Likert scale from 1 (not at all) to 11 (very severe). The following analyses contain only the first and the last value of each participant and trial. For a more detailed description of the methods and results concerning the physical and mental workload over time within each trial, see Tegtmeier et al. (2020).

2.4 Statistical analysis

Differences in RULA Grand Scores, discomfort, and physical workload across time and device were tested using mixed ANOVA with device as between factor. Bonferroni adjustment was used to account for multiple comparisons. In case Mauchly's Test indicated a violation of the assumption of sphericity a Greenhouse-Geisser correction was used. A Spearman's rank-order correlation was run to determine the relationship between the RULA general scores, the musculoskeletal discomfort, and the subjective workload ratings separated for trial. SPSS 26 was used for all analyses, with a significance criterion of $p < .05$.

3. Results

3.1 Posture

As depicted in Table 1, the final minimum average RULA Grand Score for the side holding the device lay well within level 2 irrespective of the device used. The maximum mean Grand Score falls within the range of level 3. Note that the actual mean values are located within the minimum and maximum possible values.

***Table 1**. Mean maximum and minimum mean RULA Grand Scores by trial and device (n = 64).*

trial	Grand Score	Tablet (SE)	95%-CI	Smartphone (SE)	95%-CI
1	min	3.3 (0.1)	3.11 – 3.45	3.2 (0.1)	3.05 – 3.39
	max	5.1 (0.2)	4.64 – 5.48	5.0 (0.2)	4.61 – 5.45
2	min	3.2 (0.1)	2.98 – 3.33	3.8 (0.1)	3.60 – 3.96
	max	5.2 (0.2)	4.74 – 5.63	5.1 (0.2)	4.65 – 5.54

The mixed ANOVA with device as a between factor and trial and Grand Score variant as within-factors determined that mean Grand Scores differed significantly between minimum and maximum values ($F(1, 62) = 205.46$, $p < .001$, $\eta_p^2 = .768$). There were no significant main effects of trial ($F(1, 62) = 2.89$, $p = .098$, $\eta_p^2 = .043$) or device ($F(1, 62) = 0.55$, $p = .462$, $\eta_p^2 = .009$). Though the minimum average Grand Score was higher for the smartphone users in the second trial the three-way interaction between device, trial, and Grand Score variant just failed to reach statistical significance ($F(1, 62) = 3.99$, $p = 0.05$, $\eta_p^2 = .060$).

3.2 Musculoskeletal discomfort

There were main effects of time on subjective discomfort in all eight body parts (Table 2). This was most pronounced for the neck ($F(1.69, 104.7) = 14.44$, $p < .001$, $\eta_p^2 = .189$) and shoulder discomfort ratings ($F(1.65, 102.4) = 11.34$, $p < .001$, $\eta_p^2 = .155$).

Table 2. *Mean subjective discomfort for eight body-parts by time and device (n= 64). Bold letters indicate statistically significant differences (p < .05).*

		Tablet		Smartphone		time		device	
	time	discomfort (SE)	95%-CI	discomfort (SE)	95%-CI	*p*	η_p^2	*p*	η_p^2
neck	t0	1,44 (0,12)	0,89 – 1,98	2,41 (0,37)	1,86 – 2,95	**<0,001**	0,189	**0,018**	0,087
	t1	2,16 (0,28)	1,48 – 2,83	3,19 (0,38)	2,51 – 3,86				
	t2	2,34 (0,34)	1,54 – 3,14	3,47 (0,45)	2,67 – 4,27				
upper back	t0	1,31 (0,10)	0,90 – 1,72	1,56 (0,27)	1,15 – 1,97	**0,033**	0,056	0,136	0,036
	t1	1,56 (0,24)	1,00 – 2,12	2,13 (0,31)	1,57 – 2,68				
	t2	1,81 (0,25)	1,23 – 2,39	2,22 (0,33)	1,64 – 2,80				
lower back	t0	1,72 (0,23)	1,30 – 2,14	1,47 (0,18)	1,05 – 1,89	**0,001**	0,112	0,813	0,001
	t1	2,72 (0,43)	1,99 – 3,44	2,34 (0,29)	1,62 – 3,07				
	t2	2,13 (0,26)	1,52 – 2,73	2,53 (0,33)	1,93 – 1,15				
shoulders	t0	1,20 (0,09)	0,92 – 1,49	1,44 (0,18)	1,15 – 1,72	**<0,001**	0,155	**0,042**	0,065
	t1	1,34 (0,11)	1,00 – 1,69	1,91 (0,22)	1,56 – 2,25				
	t2	1,67 (0,17)	1,13 – 2,21	2,33 (0,34)	1,79 – 2,87				
forearm	t0	1,05 (0,04)	0,99 – 1,11	1,00 (0,00)	0,94 – 1,06	**<0,001**	0,144	0,126	0,037
	t1	1,39 (0,11)	1,18 – 1,60	1,23 (0,10)	1,02 – 1,44				
	t2	1,64 (0,19)	1,32 – 1,96	1,38 (0,12)	1,05 – 1,70				
hands	t0	1,07 (0,03)	1,03 – 1,11	1,00 (0,00)	0,96 – 1,04	**0,022**	0,067	0,720	0,002
	t1	1,18 (0,07)	1,03 – 1,33	1,13 (0,08)	0,98 – 1,29				
	t2	1,25 (0,10)	0,99 – 1,51	1,27 (0,15)	1,02 – 1,53				
thumbs	t0	1,03 (0,02)	0,99 – 1,07	1,03 (0,02)	0,99 – 1,07	**0,001**	0,131	0,303	0,017
	t1	1,09 (0,05)	0,97 – 1,21	1,18 (0,07)	1,06 – 1,30				
	t2	1,19 (0,07)	1,01 – 1,37	1,32 (0,11)	1,14 – 1,50				
fingers	t0	1,17 (0,08)	1,06 – 1,28	1,00 (0,00)	0,89 – 1,11	**0,010**	0,082	0,624	0,004
	t1	1,28 (0,12)	1,05 – 1,51	1,28 (0,11)	1,05 – 1,51				
	t2	1,41 (0,15)	1,08 – 1,73	1,39 (0,17)	1,07 – 1,71				

Both neck ($F(1, 62) = 5.91$, $p = .018$, $\eta_p^2 = .087$) and shoulder ratings ($F(1, 62) = 4.30$, $p = .042$, $\eta_p^2 = .065$) revealed a main effect of device. No significant interactions between device and time occurred for any of the discomfort ratings.

3.3 Subjective physical workload

The mixed-design ANOVA revealed a main effects of trial ($F(1, 62) = 10.59$, $p = .002$, $\eta_p^2 = .146$) and time ($F(1, 62) = 137.53$, $p < .001$, $\eta_p^2 = .689$). Independent of device the last rating was more than two times higher than the first (Figure 1). Also, the first rating in the second trial was higher than in the first trial.

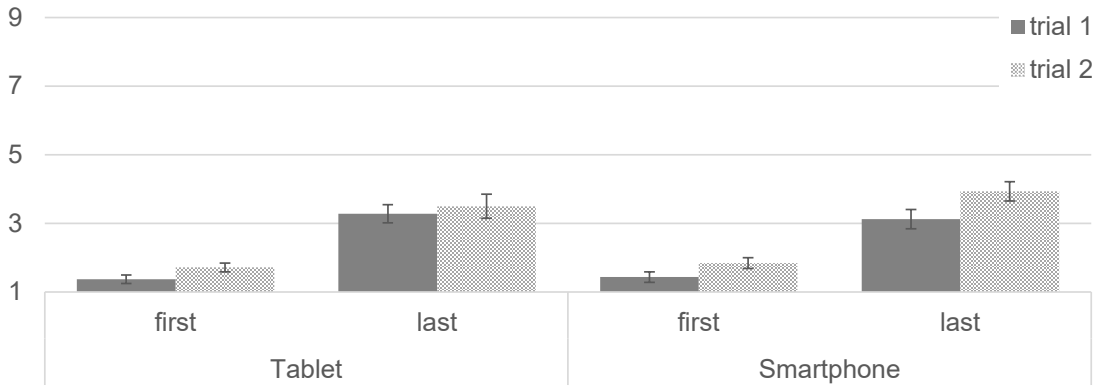

Figure 1. *Mean subjective physical workload by device, trial and rating time. Error bars indicate one Standard Error.*

3.4 Correlation between RULA scores, discomfort and physical work load

None of the participants' self-assessment of their physical workload and discomfort for the eight body parts retrieved in the first and second trial correlated significantly with the RULA scores assessed by the experimenter in the specific trials.

4. Discussion

The postures observed while documenting signify at least a low level of risk for musculoskeletal disorders, as even the minimum score exceeds the acceptable RULA scores ranging from 1 to 2. Like the results reported by Namwongsa et al. (2018), the average maximum Grand Scores indicate a much more urgent need for further investigation as well as changes in the near future. This underlines the demand to use smartphones and tablets only for a short period of time throughout the working day. However, it is still not possible to derive a specific duration from the RULA Scores obtained here.

In contrast, the subjective workload and discomfort ratings seem more in favor of smartphones and tablets as working tools. Though all ratings increase distinctly over the course of the two half hour trials, the absolute increases remain low on the 11-point scales. According to this, smartphone or tablet use for documentation tasks seems to pose no fundamental risk for employees for the time span tested.

However, there is various scientific evidence that biomechanical stress in particular is rather poorly perceived (Karwowski et al. 1999; Thompson & Chaffin 1993). The non-correlations between the subjective ratings and the RULA Scores is an indication that this may be similar for the physical aspects of smartphone and tablet use. Perception might be non-linear over time, but the time span research here is not sufficient to provide information on the course of perceived workload and discomfort while using smartphones and tablets.

Overall, it appears unsuitable based on the results presented here, to rely solely on a person's subjective tolerance in defining a time span suitable for mobile work with touchscreen devices with regard to OSH.

5. Conclusion

This study provides an indication that smartphones or tablets-pcs might be used for mobile documentation tasks at work. But, as the ergonomic risk levels observed are not negligible, it should not be the only task throughout the workday.

Furthermore, the results presented underline the significance and necessity of risk assessments in the work context, since the individual perceptions may not be a reliable measure of the physical stress caused by the use of touchscreen devices.

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